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Exam Preview:

1. In 1933, Justice Louis D. Brandeis coined the powerful phrase “sunlight as disinfectant” in support of increasing openness and transparency in public policy.
 - a. True
 - b. False
2. According to the reference material, the first U.S. law that specifically addressed identity theft was passed in ____—the Identity Theft and Assumption Deterrence Act, passed in response to the dramatic rise in identity (ID) theft in the 1990s
 - a. 1995
 - b. 1996
 - c. 1997
 - d. 1998
3. According to the reference material, U.S. companies who participated in a recent Computer Security Institute study reported losing an average of \$_____ per respondent due to viruses and \$400,000 due to another form of malware called botnet infection.
 - a. 20,000
 - b. 40,000
 - c. 50,000
 - d. 60,000
4. According to the reference material, validation is “the process of establishing an understood level of confidence that an identifier refers to a particular individual or identity.”
 - a. True
 - b. False

5. Using Table 7-1. Counts of Malicious Software Programs Across Countries, which of the following countries was mentioned in the countries with 51-115 number of reported programs?
 - a. France
 - b. China
 - c. Russia
 - d. Ukraine
6. Information exchanged to authenticate identity is often broken down into three separate classes of authenticators. Which of the following is NOT a class of authenticators discussed in the reference material?
 - a. Certificate based authentication
 - b. Password based authentication
 - c. Token based authentication
 - d. Biometric authentication
7. According to the reference material, Attribution is the analysis of information associated with a transaction or series of transactions to try to determine the identity of a sender of a stream of traffic.
 - a. True
 - b. False
8. According to the reference material, which of the following types of malware programs also often arrive via email as a downloadable file or attachment that people would want to open, such as photos, videos, or documents with misleading titles?
 - a. Computer virus
 - b. Trojan horse
 - c. Worms
 - d. Ransomware
9. The risk of malicious software is difficult to mitigate, as almost ___ percent of personal computers around the world use a variety of security solutions that have malware loaded into their memory, compared with 33.28 percent of unprotected systems.
 - a. 10
 - b. 15
 - c. 25
 - d. 50
10. According to the reference material, Section 6 of the Federal Trade Commission Act has been used with regard to privacy and security, when companies have been accused of deceptive claims regarding use of personal information.
 - a. True
 - b. False

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PREFACE

This book is a follow-on to our earlier book published in 2011 and represents a detailed look at various aspects of cyber security. The chapters in this book are the result of invited presentations in a 2-day conference on cyber security held at the City University of New York, City College, June 8-9, 2011.

Our increased reliance on the Internet, information, and networked systems has also raised the risks of cyber attacks that could harm our nation's cyber infrastructure. The cyber infrastructure encompasses a number of sectors including the nation's mass transit and other transportation systems, railroads, airlines, the banking and financial systems, factories, energy systems and the electric power grid, and telecommunications, which increasingly rely on a complex array of computer networks. Many of these infrastructures' networks also connect to the public Internet. Unfortunately, many information systems, computer systems, and networks were not built and designed with security in mind. As a consequence, our cyber infrastructure contains many holes, risks, and vulnerabilities that potentially may enable an attacker to cause damage or disrupt the operations of this cyber infrastructure. Threats to the safety and security of the cyber infrastructure come from many directions: hackers, terrorists, criminal groups, and sophisticated organized crime groups; even nation-states and foreign intelligence services conduct cyber warfare. Costs to the economy from these threats are huge and increasing. Cyber infrastructure protection refers to the defense against attacks on such infrastructure and is a major concern of both the government and the private sector.

A key contribution of this book is that it provides an integrated framework and a comprehensive view of the various forms of cyber infrastructure protection. We, the editors, strongly recommend this book for policymakers and researchers.

PART II:
LAW AND CYBERCRIME

CHAPTER 4

CHANGING THE GAME: SOCIAL AND JUSTICE MODELS FOR ENHANCED CYBER SECURITY

Michael M. Losavio
J. Eagle Shutt
Deborah Wilson Keeling

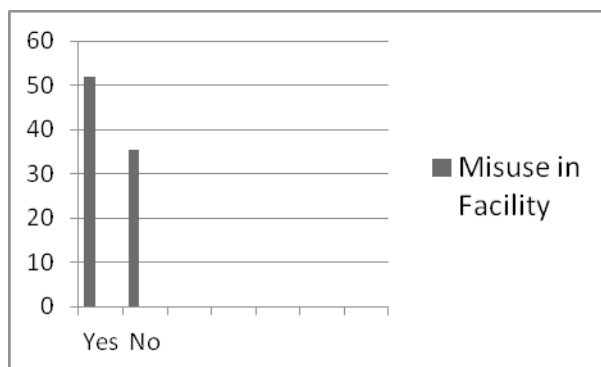
Thanks to the City College of New York, Grove School of Engineering, the Strategic Studies Institute of the U.S. Army War College and the 2009 Cyber Infrastructure Protection Conference, and Oak Ridge National Laboratory and its Cyberspace Sciences and Information Intelligence Research (CSIIR) Group and CSIIR Workshop 2010 for helping develop these themes.

INTRODUCTION

To change the game in cyber security, we should consider criminal justice and social education models to secure the highly distributed elements of the information network, extend the effective administration of justice to cybercrime, and embed security awareness and competence in engineering and common computer practice. This chapter examines models of such behavior.

A broad approach is needed, since no single group of agencies can combat cybercrime alone.¹ The approach to cyber security and cybercrime must change and expand. Traditional models for combating internal and transnational threats can assist with cyber security, even as information networks have expanded the risks to information security.

Physical security itself is insufficient, when an inmate in a correctional facility can crack the network from within the jail.² Information control via ever-smaller handheld devices is increasingly difficult. For example, almost 53 percent of inmates in one state's correctional facilities misused electronics.³ See Figure 4-1.



Source: Proceedings of IEEE Workshop on Systematic Approaches to Digital Forensics Engineering, 2010.

Figure 4-1. Percentage of Respondents Who Experienced Computer Misuse in Their Correctional Facilities.

Although the nation's homes may be castles, protected as no other space in American civil society is, that may not be true in regard to cyber security. As the 2003 *National Strategy to Secure Cyberspace* observed, these houses may offer targets of choice as sources of gain and tools for attack.⁴ The Internet puts the criminals and terrorists worldwide at our electronic doorstep, magnifying the risks and problems in addressing these information security problems. Cyber

security must address how to achieve security in such a disparate, target-rich environment as that of world-wide computing.

The *National Cyber Leap Year Co-Chairs Report* addressed the need for “game changing” approaches.⁵ One novel approach used “Cyber Economics” for developing a market-type engagement in cyber security issues. This approach proposed four economic strategies for examination via research and policy implementation for “game-changing” solutions in cyber security:

1. Mitigating Incomplete Information: Mitigate incomplete and asymmetric information barriers that hamper efficient security decisionmaking at the individual and organizational levels.

2. Incentives and Liabilities: Leverage incentives and impose or redistribute liabilities to promote secure behavior and decisionmaking among stakeholders.

3. Reduction of Attackers’ Profitability: Promote legal, technical, and social changes that reduce attackers’ revenues or increase their costs, thus lowering the overall profitability (and attractiveness) of cybercrime.

4. Market Enforceability: Ensure that proposed changes are enforceable with market mechanisms.⁶

Incentives and new liabilities would include expanded vendor, Internet service provider (ISP), registrar and registry **accountability**, **liability**, and **rewards** for protective conduct, or the lack thereof (emphasis added). The report further notes that cyber security metrics are “poorly investigated,” in that there is no accepted foundation for: (1) the information to collect; (2) the use of such information; and, (3) the weight of such information as to elements of uncertainty, inaccuracy, and error in its collection.⁷

Similarly, there are challenges to the orthodoxy of security engineering education that contend certain “myths” about security, such as the sufficiency of purely technical solutions and defense-in-depth strategies. These myths impede the creation of effective cyber security systems.⁸

CRIMINAL JUSTICE MODELS

The Application of Criminal Justice Models to Cyber Security.

In 2000, the Strategic Studies Institute (SSI) of the U.S. Army War College (USAWC) published a discussion on how criminal justice models might integrate into cyber security systems.⁹ The techniques and resources of state and local law enforcement and criminal justice entities could fit within national response. This seems appropriate, as communication networks have blurred national boundaries. The discussion also addresses the risks such an enmeshed world would create to civil society and its liberties, in which responses to attack risk “profound constitutional and security challenges” for the United States.¹⁰

Safety and security require more than technical protections and police response. They need a critical blend of those elements with individual practice and social norms. Social norms matched with formal institutions enhance public safety; this also holds true in the cyber realm.

Informal and formal modes of controlling and limiting deviant behavior are essential for effective security.¹¹ Laws, procedures, and criminal justice agencies are all modes of formal social control. Attitudes, values, and actions of individuals represent

potentially powerful informal modes. A community with a high degree of both modes will have a strong overall level of social control. These efforts must be incentivized and empowered at all levels. Where there is consonance in these two modes, there will be the greatest security.

Examples: Routine Activity Theory/Opportunity Theory and Displacement Theory.

This study suggests that the routine activity theory/opportunity theory and displacement theory – frameworks for analyzing crime in communities – are ways to conceptualize and pattern the benefits of informal social control on cyber security.¹²

Routine activities theory (RAT) posits that each of three elements contributes to a heightened or lessened risk: a suitable target, a lack of guardianship, and a motivated offender.¹³ The absence of one of these elements reduces the risk of misconduct, whereas their convergence increases it. For cyber security, the analysis should equally consider the availability of suitable targets, a presence or lack of suitable guardians, and an increase or decrease in the number of motivated offenders, particularly those seeking financial gain or state advantages.

Changes in attitudes among those who use these cyber systems can increase suitable guardians and reduce suitable targets, thereby changing the risk equation. This is a vital part of informal social control that must develop with and without technical supplements. There is no technical “patch” for ignorance.¹⁴

The overall power of social control is a function of both formal and informal controls.¹⁵ Laws, public policies, and law enforcement exemplify elements of for-

mal social control, whereas community attitudes and norms exemplify informal control. While both spheres can impede crime, states with the greatest levels of control will have high degrees of both formal and informal social control.

In cyber security contexts, high levels of informal social control are essential to deter cyber attacks, particularly since attackers exploit the anonymity and distance-collapsing features of cyberspace as vectors for attack. For example, open source software practices have led to questions regarding cyber security. Yet, this software represents a collaborative social network that self-organizes and grows as a preferentially attached network.¹⁶ Such preferential attachment to cyber security can promote a distributed security regime through commitments to competent and suitable guardianship of the nodes and network around the subject code project.

Online social networks suggest opportunities for the examination of RAT-based security promotion. Facebook, MySpace, and LiveJournal are all online social networks that promote cyber security both within and outside their domains. The observation, reporting, and notice/alert possibilities of network members who are competent and committed to security and protection can expand the guardianship network for anomalous behavior; they may also serve to reduce target vulnerability directly.

The information social network for the open source encyclopedia, *Wikipedia*, is another example of a community of guardians that has been successful in securing the information it presents. It may also serve as an example of risks due to its uncertainty of information assurance in topic areas lacking extensive guardian participation. The possibilities of such social networks

for enhancing cyber security are significant, if realized. Alan Mislove, Massimiliano Marcon, Krishna Gummadi, Peter Druschel, and Bobby Bhattacharjee found that online social networks have small-world and scale-free properties based on power-law; these would indicate potential for the expansion of a guardian security regime.¹⁷ Others contend that though some aspects of RAT can apply to criminal activity involving computing systems, there are key differences that limit the utility of the model.¹⁸ The collapse of the social network may degrade the security of information.¹⁹ There must be vigilance in seemingly normal activity used to mask an attack.²⁰

Consider M. Felson and R. V. Clarke's 10 principles of crime opportunity theory:²¹

1. Opportunities play a role in causing all crime.
2. Crime opportunities are highly specific.
3. Crime opportunities are concentrated in time and space.
4. Crime opportunities depend on everyday movements of activity.
5. One crime produces opportunities for another.
6. Some products offer more tempting crime opportunities.
7. Social and technological changes produce new crime opportunities.
8. Crime can be prevented by reducing opportunities.
9. Reducing opportunities does not usually displace crime.
10. Focused opportunity reduction can produce wider declines in crime.

Figure 4-2. Ten Principles of Opportunity and Crime.

These principles may be mapped to a variety of technical and nontechnical factors that enhance or diminish cyber security. Identifying opportunities and

mitigating them are a major focus of information security research in finding technical vulnerabilities of systems. These vulnerabilities are specific and limited to the user space of a specific system, particularly those of typical system use. Once an exploit is found and used, its use will be replicated in other situations. Mitigation of these exploits may be both technical and nontechnical.

Certainly the expansion of social conduct into the online world has produced new crime opportunities within technology. As in other situations of expanding crime and social deviancy, the application to reduce these opportunities can have a beneficial effect in reducing cybercrime. Technical solutions certainly help, just as strong doors and locks help, but other factors, such as personal vigilance for self and neighbors and assured punitive response, can help as much or even more. These measures accord with the solution features suggested in the *National Cyber Leap Year Co-chairs Report*.²²

Another application of criminological principles to cyber security relates to the use of criminal profiling and behavioral analysis.²³ The reactive use of these techniques, much like the use of technical digital forensics in network settings, serves to focus an investigation and response in particular areas and on particular individuals. This, in some cases, may be as limited as the method of operation (*modus operandi*, or “MO”) of a particular miscreant. But the reactive use goes beyond this to distinctive behaviors of individuals that are *a priori* and may lead to the use of particular operational methods or tools.

Proactive use of profiling deters, or prevents, crimes such as drug courier profiling. Frank Greitzer, Deborah Frincke, and Mariah Zabrieski discuss this in

relation to the application of traditional security techniques to the identification of insider cyber security threats.²⁴ The set of circumstances that have been associated with motives or disinhibitions leading to insider criminal activity, such as fraud or violence, may also match with insider cyber security breaches. The researchers note that, “Assessing ability, opportunity, and motivation is a primary decisionmaking task underlying the threat analysis.”²⁵ These factors may then map to information and network metrics as part of an enhanced alert for potential or actual threats to information security.

J. L. Krofcheck and M. G. Gelles,²⁶ note these non-technical life factors and characteristics as risk indicators for insider cyber security threats:

- Non-U.S. citizen,
- Major life change,
- Access to classified information,
- System administrator rights,
- High level of computer skills and knowledge,
- Intermittent work history,
- Family/marriage issues,
- Legal issues,
- Credit/debt problems,
- Past or current arrest/criminal activity, and
- Strong interest in Blackhat community.

In turn, these indicators also present ethical and administrative issues with this security analysis, creating possible problems due to the possible invasion of privacy, and false suspicions that undermine both the reputations and morale of staff.

But there is the risk of creating hyper-romantic myths of profiling effectiveness. No profile alone has

led to an arrest; rather, it is a directive tool of investigation that may be most effective when psychopathologies are present.²⁷

SOCIAL AND EDUCATION MODELS

Cyber Security Awareness through Teaching Community Engagement.

Opportunities for invasion are reduced when a system user recognizes the risks and personally mitigates them. This could be as simple as not opening an email attachment from an unknown correspondent or permitting an unknown program permission to run. Such security could be achieved through the engagement of computer engineering students to broaden their understanding of their responsibilities to both the profession and to the public.

As with community safety relating to violent crime, cyber security requires effort and engagement, including general computing competence. But, there is little formal training in this area for the general public who are the most at risk. A model for such an engagement that would provide this training and awareness appears below.

The National Science Foundation-funded effort produced the *Information Assurance and Security Ethics in Complex Systems: Interdisciplinary Perspectives*, to demonstrate the value of an interdisciplinary approach to cyber security development. This approach compiles many different and highly novel perspectives on information security and assurance, and encompasses a broader review of the consequences of failure than is traditionally addressed.

This collection begins with the challenge of how people view any problem and the natural tendency toward self-reference in framing issues. This may be quickly placed in the cyber security space, with computer engineering students directed to identify threats and responses. Through use of chapters dealing with “Social/Ethical Issues in Predictive Insider Threat Monitoring,” “Peer-to-Peer Networks: Interdisciplinary Challenges for Interconnected Systems,” and “Responsibility for the Harm and Risk of Software Security Flaws,” students may then understand the greater complexity they face in security solutions as well as the legal and ethical consequences of failure in cyber security. Through their novelty, these perspectives push students to uncomfortable discussions that, in turn, may lead to better understanding of the challenges faced in order to achieve effective cyber security. These difficult discussions need to take place if there is to be effective security for our information and people.

Extending this information beyond the classroom becomes the next challenge.

An Information Security Model.

One model for expanding the discussion into real-life application implements the use of computer engineering students to handle community projects relating to cyber security. The Department of Computer Engineering and Computer Science at the University of Louisville introduced a community engagement/community-based learning/service learning component to its 500-level course on information security in the summer of 2009. This course, in addition to examining engineering, technical, and scientific founda-

tions of data security, addressed issues relating to the administrative and practical implementation of secure computing practices. The community engagement/service learning component required the students to examine user responsibilities and their computer related needs. The students also implement a program to teach non-expert computer users safe and secure computing practices. This, in turn, allowed them to examine the foundations essential to information security and how to teach and communicate with others. The University of Louisville Engineering School has an extensive cooperative education program requiring students to work in industry. This community engagement/service learning component, however, requires the students to examine the interaction of computing systems with typical, non-expert users.

Service learning and community engagement components in 2009-10 courses on Information Security were directed at “authentic” issues of secure broad community deployment, the use of broadband services, the security of existing personal and small business systems, and user training.²⁸ In addition to laboratory and design work, students created and implemented a detailed, low-level training program to community groups on user risk, conduct, and responsibilities related to online security. Training was administered in single presentations to various age groups ranging from elderly and retired individuals to elementary school students, with a focus on low-income communities. The following year, this program evolved into small group/one-on-one sessions with the targeted users.

Data Analysis and Outcomes for Students.

An assessment of student learning outcomes revealed that through the service learning/community engagement component, students had enhanced learning related to issues of information security.²⁹ Of the respondents, 66 percent agreed that the engagement component, "... helped me either connect what I learned to real-life situations or contributed to knowledge in the discipline." Three-fourths agreed that it, "... provided me an opportunity to apply skills and knowledge I have gained from my major courses." The 2009 community presentation on information security scored well when compared with other components in connecting learning to real-life problems, as shown in Figure 4-3.

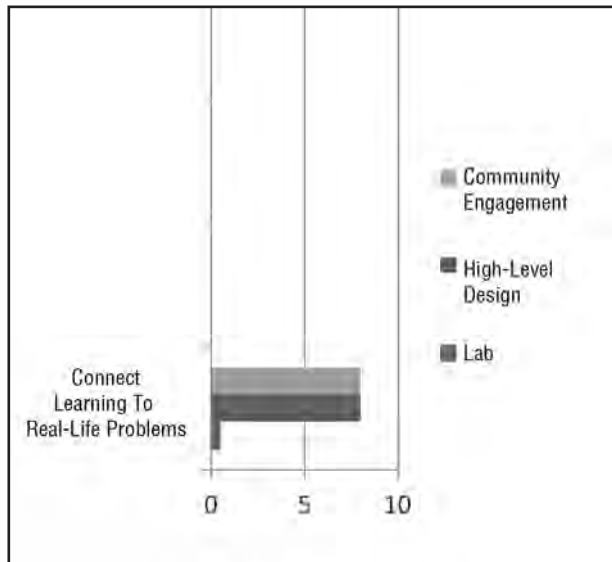


Figure 4-3. Effectiveness in Connecting Learning to Real-Life Problems.

The program allowed students to address authentic issues in the discipline of Information Security, as detailed in Figure 4-4, with nearly three times as many students finding the community engagement component connected them to an authentic experience within their discipline as compared with the system design or laboratory components.

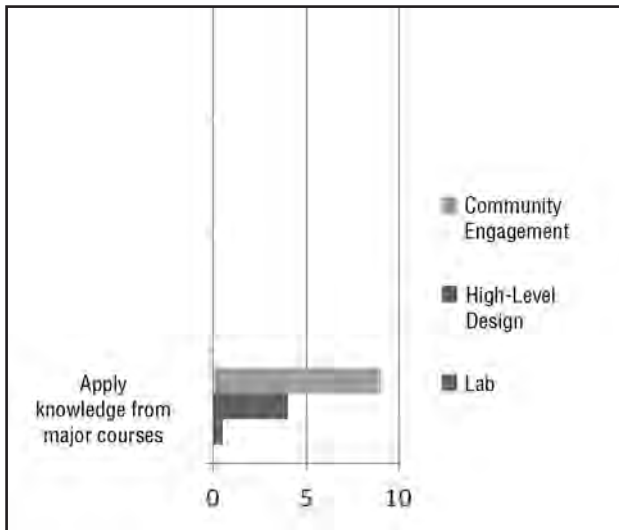


Figure 4-4. Application of Skills and Knowledge from Major Courses.

This indicates value in such teaching and learning components for the students themselves.

The benefit and improvement in cyber security by those in the community receiving the training was studied in 2010 via surveys of the several site supervisors. Those surveys similarly indicated positive experiences with the training. The respondents agreed that the presentations covered new information on security for their target groups and improved the safe practices of those using computers.

The response from the site supervisor for the senior citizens residential facility provided anecdotal comments that indicated additional concerns about both a desire to access online services and a need for fundamental skills. These comments, from individuals ranging from 67 years of age to 88 years of age, noted:

- I want to get online when I learn the basics of how to use a computer. Seniors are unable to help other seniors. They do not have the patience or skills to explain things to other seniors. Every time you turn around, you need to have a computer. You can't enter a contest or shop online. If you want to learn more about a particular news story, they tell you to go online. Many free discount coupons are only available online.
- All my family has computers, and they talk back and forth to each other. I would love to be with them.
- Keyboard would be difficult, but I would love to do family history research.
- The students made my computer faster, much faster. We did not get into a discussion about security (the main concern was about medical information).
- I never order anything on the computer. I have heard too many stories of persons losing everything by giving out credit information.
- Students helped with setting up my games. I still have pop ups and must restart the games.

These responses demonstrate both the need and desire for skills in secure, competent computing. The program offers a way to distribute security awareness

and skills that meet the requirements of criminal justice theory and provide learning objectives within the discipline of computer engineering.

The National Collegiate Cyber Defense Competition.

The National Collegiate Cyber Defense Competition brings together students from universities who compete regionally and then nationally to protect computer systems from cyber attacks. Lieutenant General Harry Raduege, Jr. (USAF, Ret.), chairman of the Deloitte Center for Cyber Innovation and co-chairman of the Commission on Cyber Security for the 44th presidency, has noted, "These exercises are vital training for people who will be safeguarding the nation's systems and infrastructure."³⁰

To prepare for the computer attacks of the future, the competing students must successfully defend their computer network against hostile attacks while maintaining operations in regional and national competition. Attacks against their systems are conducted by penetration testers from the industry.

This is an intensive laboratory experience for the next generation of cyber defenders. It is another example of a social/education model for developing cyber security skills across the operational spectrum in an environment close to the real world, with all the complexities, ambiguities, and stresses it entails.³¹

FUTURE DIRECTIONS

Areas of study and testing in expanding cyber security are recommended. This must move from concept to pilot models that one can measure for ef-

fectiveness. In the limited examples described here, data on the effectiveness of the training systems are one area that requires further study to establish firmly the benefit of this model. The testing and data on pilot projects is the next step to enhancing guardianship roles and hardening targets. For example, the Cyber Clean Center project of the Japanese Computer Emergency Response Team Coordination Center is a cross-disciplinary collaboration between JP-CERT, Trend Micro, ISPs, and various security vendors – the goal of which is to create a guardian network against botnet compromise and exploitation.

Participating ISPs operate decoy honeypot machines on their networks that serve as sensors for botnet activity. They log the Internet protocol (IP) addresses of infected machines, from which the ISPs notify the infected user of the compromise and offer a “BOT disinfestation website” with easy, clear instructions and downloadable tools to clean their compromised machines.³² The system is dynamic, with analysts monitoring sensor activity and creating “disinfestation” tools directed toward new threats.

The activity report data for April 2010 show a cumulative number of 484,583 (7,561 for April) alert emails sent to 100,696 (3,751 for April) recipients, with a cumulative download rate of disinfestation tools of 31.8 percent.³³ The CCC data offer an opportunity to evaluate the effectiveness of methods, such as this one in enhancing security, particularly as an application of the guardian roles in enhancing cyber security.

Melissa Hathaway, a cyber security expert during the George Bush and Barack Obama administrations, has suggested the online game “The SmokeScreen Game” as a novel way to promote secure behavior.³⁴ The SmokeScreen Game is a British project that lets students test life online through social media and their

interactions with others in the electronic world. The SmokeScreen Game addresses lies, malice, misinformation, and criminal online conduct, allowing young people to test these parameters in a simulation before being caught in a potentially damaging reality.

Lastly, the 2011 service learning and community engagement components will continue to collect additional data on the effectiveness of this model. Computer engineering students in the junior-level course on legal, ethical, and social issues in computing have begun more fundamental work with community members on competent computing—expanding the base of skills and producing additional data on basic user needs.

CONCLUSION

Cyber security is yet another facet of security in an uncertain world, an issue people have sought to address throughout human history. It requires global attention, not a belief that “police action” can solve all risks. Cyber security can be enhanced through the use of criminal justice and social education models to secure the highly distributed elements of the information network. It can extend the effective administration of justice to cybercrime and embed security awareness and competence in the use of pervasive and ubiquitous computing via novel and creative ways to engage people in their own online cyber security.

Because this is happening swiftly in an expanding world of cyber consumers that has outstripped our traditional educational system, special efforts must be made to engage citizens in protecting this new, rich environment for learning, commerce, and society. Failure to do so will only expand the pool of victims, potential and real.

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31. The engineering students competing for the University of Louisville in 2011 were Eric McDowell, Team Captain; Joseph Stigers, Assistant Team Captain; James Gissendaner; Henry John Paul Frederick; James Corcoran; Justin Cottrell; Joshua Chase; Jimmy Murphy; and Tu Nguyen.

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CHAPTER 5

AN INSTITUTIONAL AND DEVELOPMENTAL ANALYSIS OF THE DATA BREACH DISCLOSURE LAWS

Melissa Dark

This chapter is based on an earlier, extended version of a chapter that appears in Melissa J. Dark, ed., “Information Assurance and Security Ethics in Complex Systems: Interdisciplinary Perspectives,” Hershey, PA: IGI Global, available from www.igi-global.com, posted by permission of the publisher.

INTRODUCTION

Although advances in computing promise substantial benefits for individuals and society, trust in computing and communications is critical in order to realize such benefits. The hope for cyber trust is to create a society in which trust enables technologies to support individual and societal needs without violating confidences and exacerbating public risks. Cyber trust, in part, depends on software and hardware technologies upon which people can justifiably rely. However, the cyber trust vision requires looking beyond technical controls to consider how other forms of social control contribute to a state of cyber trust. As information technology has become more ubiquitous and pervasive, assurance and security concerns have escalated; in response, there has been noticeable growth in public policy as a form of social control to bolster cyber trust. One can see such growth just by

briefly inventorying some of the regulations enacted to protect security and privacy:

- Freedom of Information Act (1966)
- ProFair Credit Reporting Act (1970)
- Bank Secrecy Act (1970)
- Privacy Act (1974)
- Family Educational Rights and Privacy Act (FERPA) (1974)
- Right to Financial Privacy Act (1978)
- Foreign Intelligence Surveillance Act (1978)
- Electronic Communications Privacy Act (ECPA) (1986)
- Telephone Consumer Protection Act (1991)
- Communications Assistance for Law Enforcement Act (1994)
- Driver's Privacy Protection Act (1994)
- Health Insurance Portability and Accountability Act (HIPAA) (1996)
- Computer Fraud and Abuse Act (1996)
- Children's Online Privacy Protection Act (COPPA) (1998)
- Digital Millennium Copyright Act (1998)
- Gramm-Leach-Bliley Act (GLBA) (1999)
- USA PATRIOT Act (2001)
- Federal Information Security Management Act (2002)
- Fair and Accurate Credit Transactions Act (2003)
- CAN-SPAM Act (2003)
- 46 State Data Breach Disclosure Laws* law (2003-present).

*The U.S. Virgin Islands, Puerto Rico, and the District of Columbia have also enacted data breach disclosure laws.

This is not an exhaustive list, but it is representative and exemplifies the increasing growth in legislation. Given that information security and privacy are becoming more important, as evidenced by the growth in public policy, policy analysis in this area is timely and relevant.

Policy analysis aims to address questions such as the following. What do governments choose to do or not to do? How effective are the proposed or enacted solutions to public problems? How are issues that affect large numbers of citizens introduced to the public arena? What are the historical, political, and institutional factors that shape the formulation of public policy? In light of the relationships among policies, which of the various alternative policies will be most effective in achieving a given set of social goals? How can policymaking improve through research and analysis?

This chapter considers the data breach disclosure laws recently enacted in most of the United States. There are three important factors that make the state data breach disclosure laws of interest: the rapid policy growth; the first concrete example of informational regulation for information security; and the importance of these laws to prevent identity theft and protect privacy. The chapter begins with a discussion of the policy analysis framework used for this analysis. Thereafter, the chapter offers a retrospective analysis of the historical, political, and institutional factors that gave rise to these laws, i.e., the legislative outcomes seen today. Finally, the chapter concludes with suggestions for information security and privacy policy in the future.

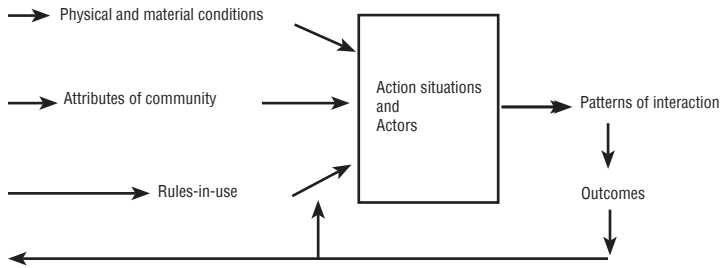
INSTITUTIONAL ANALYSIS AND DEVELOPMENT FRAMEWORK

The institutional analysis and development (IAD) framework is a tool for performing policy analysis that focuses on how institutions, i.e., structures and mechanisms of social order, govern behavior. The goal of using this framework is to organize one's inquiry into a subject, which in this chapter are the data breach disclosure laws. The IAD framework is associated with the social theory of new institutionalism, which grew out of a desire to study institutions from a sociological perspective. Whereas old institutionalism studies formal institutions—such as organizations, norms, laws, and markets—new institutionalism adds the study of how institutions operate in a sociological context. In new institutionalism, institutions are abstractly defined as “shared concepts used by humans in repetitive situations organized by rules, norms and strategies.” (Ostrom, 1999, p. 37) New institutionalism considers topics such as how individuals and groups construct institutions, how institutions function in practice, how institutions interact and affect each other, the effect that the sociological environment has on these interactions, and the effects of institutions on society. In new institutionalism, institutions are both the entities (organizations, laws, and markets) themselves, as well as things—rules, norms, and strategies—that shape the patterns of interaction across these entities.

While rules and norms are powerful, they are largely invisible, which makes identifying and measuring them difficult (Ostrom, 1999). One can describe them, but not precisely. This is important, since readers of this chapter will clearly see qualitative descriptions to depict institutions in action, but not quantita-

tive measures. As a result, the description of this type, by its nature, includes connotation, which cannot be avoided; norms exist in us, not apart from us. Therefore, this chapter is subject to the author's bias. Readers must refute and/or improve upon this work. It is incumbent on all who are interested in such research to be aware of, and guard against, personal biases where they may limit findings.

The IAD framework appears in Figure 5-1. The action arena in the middle of the figure includes the action situations and the actors. In describing the action situation(s), the analyst attempts to identify the relevant structures, i.e., those affecting the process of interest. This can include participants; allowable actions, and linkages to outcomes; the level of control that participants have over choice; information available to participants; and costs and benefits assigned to actions and outcomes. The analyst also identifies the pertinent actors. Actors are individuals and groups (entities) who take action, i.e., they behave in a manner to which they attach meaning, either subjectively or instrumentally. Moving to the right in Figure 5-1, the IAD model includes patterns of interaction and outcomes. Most social reality includes multiple action arenas that interlink; some may say they are entangled. The IAD framework calls out patterns of interaction as subjects of interest in their own right as well as in relation to action situations and actors, and to outcomes. Outcomes are observed, inferred, and/or expected behaviors or results.



Note: Adapted from P. Sabatier, 1999.

Figure 5-1. Institutional Analysis and Development Framework.

Moving to the left of the framework, action arenas can also be dependent variables. In this way, the analyst looks at how rules-in-use, attributes of community, and physical/material conditions influence the action arena. Rules-in-use are shared understandings about what is expected, required, and allowed in ordering relationships. Physical/material conditions refer to the characteristics of the states of the world as they shape action arenas. Clearly, what is expected or allowed may be conditioned by what is physically or materially possible. Likewise, physical conditions might shape rules-in-use and vice versa. Attributes of community are nonphysical conditions that provide structure to the community. Attributes of community may or may not be shaped by physical conditions and can serve to influence rules-in-use and the utilization of physical conditions. Moving right to left in the IAD model, one can also study how outcomes influence physical conditions, attributes of community, and rules-in-use. Consistent with the new institutional paradigm, the IAD model assumes that social systems

are continually constituted and reconstituted; in this way, both the systems and the models to analyze them are organic in their worldview.

The IAD model does not prescribe how analysis is performed. The arrows do not mean to suggest that the analyst needs to work through the model in full, or from left to right. For example, an analyst can work from 1) the action arena to 2) outcomes in an effort to discern or predict patterns of interaction. Another alternative would be to work from 1) observed outcomes to 2) effects thereof on rules-in-use or attributes of community. Or the analyst can work across levels, e.g., investigating how collective choice rules-in-use such as excludability and the free-rider problem influence what type of operational policy can be enacted. This ability to study multiple aspects of an institution simultaneously is the power of this model. The IAD model is especially useful for analyzing self-governing entities; self-governing entities are comprised of individuals who create and influence the rules that structure their lives. In other words, the members (or their representatives) of a self-governing entity participate in the development of the collective-choice and constitutional rules-in-use. Self-governing entities are complex, adaptive systems in that they consist of a large number of elements interacting in multiple ways; the interactions change the system, which shapes future interactions such that outcomes are hard to predict, and thus, considered emergent. Self-governing entities are polycentric, in which citizens organize multiple governing authorities and private arrangements at different scales. A constitutional government is a self-governing entity; in an interesting contrast, the Internet is also a self-governing socio-technical entity. Public policy in information assurance and security is

about how a polycentric system governs a polycentric system, making the IAD framework a useful analytic tool for this paper.

Retrospective Analysis.

The retrospective analysis examines rules-in-use, attributes of community, and the physical and material conditions that served to shape the policy actions we have seen to date in information security and privacy. Given that the data breach disclosure laws aim to ameliorate identity theft and privacy concerns, we start with an overview of other legislation in these areas.

Policy Actions to Date.

The first U.S. law that specifically addressed identity theft was passed in 1998—the Identity Theft and Assumption Deterrence Act, passed in response to the dramatic rise in identity (ID) theft in the 1990s. Prior to this act, ID theft was not regulated per se. With regard to privacy, there is no provision for privacy in the U.S. Constitution. There is no independent privacy oversight agency in the United States, and the United States has no comprehensive privacy law. Instead, the United States has taken a sectorial approach to privacy regulation so that records held by third parties—such as financial and personal records at banks, educational and personal records at universities, membership and personal information at associations, and medical and personal records at community hospitals—are generally not protected unless a legislature has enacted a specific law. As a result, we have a patchwork of laws enacted to address privacy and data security. These

are outlined next, starting with the laws that pertain to the federal government, followed by laws that pertain to the private sector, and finally, state laws.

Federal Laws.

The Federal Trade Commission (FTC) Act was established by the Federal Trade Commission in 1914 for the purposes of promoting consumer protection and eliminating and preventing anticompetitive business practices. Jurisdiction of the FTC Act extends to a variety of entities. Section 5 of the FTC Act forbids unfair or deceptive practices in commerce, where unfair practices are defined as those that cause or will likely cause substantial injury to consumers. Section 5 of the Federal Trade Commission Act has been used with regard to privacy and security, when companies have been accused of deceptive claims regarding use of personal information (e.g., Choicepoint). In 2003, the FTC Act was amended to include a provision regarding the privacy of consumers' credit data (the Fair and Accurate Transactions Act of 2003 - 15 U.S.C. 1681-1681x).

The Privacy Act of 1974 (5 U.S.C. 552a) governs the federal government's information privacy program. The intent of the Privacy Act is to balance the government's need to maintain information about individuals and the privacy rights of individuals. The Privacy Act protects individuals against unwarranted invasions of privacy stemming from federal agencies' collection, maintenance, use, and disclosure of personal information (U.S. Department of Justice, 2008). The U.S. Congress passed the act in response to revelations of privacy abuse during President Richard Nixon's administration. A second goal of the Privacy Act is to address potential abuses stemming from the

government's increasing use of computers to store and retrieve personal data. The Privacy Act focuses on four basic policy objectives:

1. To restrict the disclosure of personally identifiable records maintained by federal agencies.
2. To grant individuals increased rights of access to federal agency records that pertain to themselves.
3. To grant individuals the right to seek amendment of federal agency records maintained on themselves, given evidence that the records are inaccurate, irrelevant, untimely, or incomplete.
4. To establish a code of "fair information practices" that requires federal agencies to comply with statutory norms regarding collection, maintenance, and dissemination of records.

The Privacy Act specifies that agencies will not disclose any record contained in a system of records by any means of communication to any person or to another agency without the prior written consent of the individual to whom the record pertains—barring exceptions such as law enforcement. The Privacy Act also mandates that each federal agency have in place an administrative and physical security system to prevent unauthorized release of personal records. While the Privacy Act also applies to records created by government contractors, it does not apply to private databases.

The Federal Information Security Management Act (44 U.S.C. 3544) (FISMA), enacted in 2002, is the principal law governing the information security program for the federal government. FISMA calls for agencies to develop, document, and implement agency-wide information security programs. This includes information systems used or operated by an agency or by

a contractor of an agency. A goal of FISMA is to see that information security protections are commensurate with the risk and magnitude of harm resulting from unauthorized access, use, disclosure, disruption, modification, or destruction of information collected or maintained by or on behalf of the agency. FISMA requires procedures for detecting, reporting, and responding to security incidents. Notification of security incidents must be provided to a federal information security incident center, law enforcement, and relevant Offices of the Inspector General. The Office of Management and Budget Breach Notification Policy, issued in 2007, reemphasizes agencies' obligations under the Privacy Act and FISMA by outlining two new privacy requirements and five new security requirements, which include explicit requirements for breach notification.

The Veterans Affairs Information Security Act (38 U.S.C. 5722) was enacted in 2006 in response to the May 2006 breach of 26.5 million veterans' personal data. The Veterans Affairs Information Security Act requires the Veterans Administration (VA) to implement agency-wide information security procedures to protect the VA's sensitive personal information and information systems. While the VA Secretary must comply with FISMA, this act includes other requirements not in FISMA, which are not specified here due to the narrow scope of this law, i.e., it applies only to the VA.

Private Sector Laws.

In addition to the laws that shape the behavior of federal agencies, a suite of information security and privacy laws apply to the private sector. The two main

laws are the Health Insurance Portability and Accountability Act (42 U.S.C. 1320) of 1996 (HIPAA) and the Gramm-Leach-Bliley Act (15 U.S.C. 6801-6809), enacted in 1999 (GLBA). HIPAA requires health plans, health care clearinghouses, and health care providers to ensure the privacy of medical records and prohibits disclosure without patient consent. While HIPAA includes privacy provisions, it is important to note that the primary purpose of HIPAA was job mobility. According to Hinde:

It was perceived that the disclosure of pre-existing medical conditions or claims to a new employer and that employer's health plan might discourage job mobility if those conditions were excluded by the new health plan insurer. Thus, the concept of providing privacy over identifiable information for those covered by the plan (Hinde, 2003, p. 379).

The security standards that require health care entities to maintain administrative, technical, and physical safeguards to ensure the confidentiality, integrity, and availability of electronic "protected health information" were added to HIPAA in 2003 .

The Gramm-Leach-Bliley Act (GLBA) pertains to financial institutions. The impetus for GLBA was to "modernize" financial services. This included the removal of regulations that prevented the merger of banks, stock brokerage companies, and insurance companies. These financial institutions regularly bought and sold information that many would consider private, including bank balances and account numbers. Therefore, the:

(R)emoval of these regulations raised significant risks that these new financial institutions would have ac-

cess to an incredible amount of personal information with no restrictions upon its use. Prior to GLBA, the insurance company that maintained your health records was distinct from the bank that mortgaged your house and the stockbroker that traded your stocks. Once these companies merged, however, they would have the ability to consolidate, analyze, and sell the personal details of their customers' lives (EPIC, 2008).

GLBA requires financial institutions—businesses that engage in banking, insuring, stocks and bonds, financial advice, and investing—to safeguard the security and confidentiality of customer information, to protect against threats and hazards to the security or integrity of these records, and to provide customers with notice of privacy policies. Section 501 (b) of GLBA requires banking agencies to establish industry standards regarding security measures such as risk assessment, information security training, security testing, monitoring, and a response program for unauthorized access to customer information and customer notice. In this way, GLBA is self-regulatory because it calls for financial institutions to appoint an intermediary to determine best practices for information security and to monitor the performance of financial institutions against these industry standards.

State Data Breach Disclosure Laws.

The most recent spate of activity is in the 46 state data breach disclosure laws. California was the first state to establish a data breach disclosure law in 2003; 10 other states enacted laws in 2005, 19 in 2006, eight in 2007, five in 2008, two in 2009, and one in 2010. Questions and concerns about the efficacy of these laws are many. All of these laws address three com-

mon elements: personal information definition, notification requirements, and notification procedures and timelines. However, the definitions of “personal information,” “breach,” “encryption,” and “potential risk” are not consistent across the various state laws. This creates challenges for companies that operate in more than one state. The need to comply with multiple state laws can be cumbersome and costly. Thus far, it is not known if consumer notification is effective and under what circumstances. Given that the laws vary with regard to what is protected, to what degree, and when, consumer advocates fear that that lack of consistency diminishes the effectiveness of the laws. By allowing consumer rights to vary, consumers lose their power and, as a result of their protections meaning many different things, these consumer protections mean no one thing. Questions also arise about the use of personal notification as a mitigation strategy. As notifications increase, there is an increased risk of consumer desensitization, which ironically could cause consumers to be inattentive to the risk, which would be counterproductive.

The clarion call is that we are drowning under a myriad of different state data breach notification laws, thereby making a federal data breach notification law imperative. In response, 15 federal data breach notification bills have been introduced in the past 4 years. While all of these bills are dead, the discussion of preemptive federal law continues. The debate continues as to the needs of business versus consumer groups. As business vies for a high threshold for notification due to the fact that notification costs time, money, and reputation, consumer groups contend that higher thresholds do not grant enough notice to consumers. Questions of what *should be* with regard to identity theft, privacy, and security remain salient.

Retrospective Policy Analysis.

We now turn to a discussion of the policy analysis using the IAD framework to consider why and how we arrived at the development of the 46 existing data breach laws. In this retrospective analysis, we consider the rules-in-use, attributes of community, and the physical and material conditions that served to shape the policy actions we have seen until now. To date, public policy in information security and privacy in the United States has been largely incremental in nature. We can see from the patchwork of laws discussed earlier in this chapter that we have thus far resisted a coordinated federal law that preempts existing legislation. Incrementalism is common in self-governing, polycentric entities. In policy analysis, incrementalism assumes that: 1) the effects of seriality enhance outcomes by reducing uncertainty; and, 2) the enhanced consideration of context enhances outcomes. That the information age has introduced a number of uncertainties makes incrementalism especially relevant.

Stated more directly, and in connection to the IAD model, one of the rules-in-use is incrementalism. When there is a high degree of uncertainty, policy will be enacted incrementally. Thus, a plethora of laws is to be expected. While identity theft is nothing new, the magnitude of identity theft experienced in the past decade is new. The global information infrastructure is in its infancy – it is still unclear what people will and will not do in the electronic frontier. The Internet was never designed to serve the myriad of purposes for which it is being used, nor was it designed for billions of users. Laws designed in the industrial era may or may not apply in the information age. It is not certain what new laws are necessary as a result of information technologies and how effective these laws will be.

During this period of transition, new communities form and existing communities are being reshaped; as a result, behavioral norms are being renegotiated. Given the global nature of the Internet, it is reasonable to view these communities as more heterogeneous or, at a minimum, heterogeneous in new ways. Therefore, norms cannot be easily transported based on existing communities; they will have to be established from the ground up, which is bound to take time. Additionally, because the technology is still new, scientists and engineers are still determining what actions are physically possible. Talented individuals around the world are working on technologies to help anonymize data, enhance privacy-preserving computation, and provide improved intrusion detection, but this takes time as well. Experience in all of these areas — rules-in-use, attributes of community, and physical/material conditions — occur through observation, involvement, and exposure.

Though we do not have much experience, there has been the need to take action. ID theft is on the rise, which concerns citizens. Two of the core imperatives of the state are domestic order and legitimacy (Dryzek, Downes, Hunold, Schlosberg and Hernes, 2003). Yet, the existing federal and private sector laws are not sufficient to address the rising identity theft problem threatening domestic order, thereby forcing lawmakers to take action to ensure their perceived legitimacy. In response, federal laws have been amended, private sector laws are being tweaked, and a flurry of state laws have been enacted. To what can we attribute the incremental changes we have observed? Why do we have these laws as opposed to something else? To answer these questions, we turn to a discussion of openness and transparency, informational regulation,

the infancy of the information industry, and federalism; we further examine how rules-in-use, attributes of community, and physical/material conditions have intersected in each of these areas to produce the policies we have today.

Openness and Transparency.

A democracy is founded on principles of openness and transparency. In 1933, Justice Louis D. Brandeis coined the powerful phrase “sunlight as disinfectant” in support of increasing openness and transparency in public policy. While laws that aim to ensure openness and transparency in government operations existed before 1933, Brandeis is responsible for the term “Sunshine Laws.” The impetus behind sunshine laws is twofold. First, a thriving, open democracy depends on open access and citizen participation; thus, the right-to-know is a constitutional and inherent right of American citizens. Second, a government that is of the people, for the people, and by the people asserts government subservience to the individual, which predicates freedom of information.

The Freedom of Information Act (FOIA), signed into law on July 4, 1966, by President Lyndon B. Johnson, is a Sunshine Law. FOIA allows for the full or partial disclosure of previously unreleased information and documents controlled by the U.S. Government. The concept of “freedom of information” conveys a philosophy that values the advantages of increasing our ability to gather and send information, and clearly does not connote privacy as a positive right. This acts as a rule-in-use.

The Privacy Act of 1974 arrived 8 years later as an amendment to the FOIA in response to Watergate and the abuse of privacy during the Nixon administration.

The Privacy Act of 1974 did not promote privacy, but established a code of fair information practice. It was also an attempt to limit the powers of government and passed hastily during the final week of the 93rd Congress, which was in session from 1973-74. According to the U.S. Department of Justice:

[N]o conference committee was convened to reconcile differences in the bills passed by the House and Senate. Instead, staffs of the respective committees—led by Senators Ervin and Percy, and Congressmen Moorhead and Erlenborn—prepared a final version of the bill that was ultimately enacted . . . the Act's imprecise language, limited legislative history, and somewhat outdated regulatory guidelines have rendered it a difficult statute to decipher and apply (U.S. Department of Justice, 2008).

Moreover, even after more than 25 years of administrative and judicial analysis, numerous Privacy Act issues remain unresolved or unexplored. Adding to these interpretational difficulties is the fact that many Privacy Act cases are unpublished district court decisions.

This offers important insight into the historical context with regard to how information and privacy are embedded in the past as well as food for thought on how this norm has shaped our ongoing collective treatment of it going forward. Through the enactment of FOIA in 1966, the push to enable information sharing was a result of mistrust in government. Eight years later, the Privacy Act was reactive in nature and reflective of further distrust of government. Through these pieces of legislation run two noteworthy threads. First is the value of freedom of information, wherein information belongs to and exists for the advancement of

citizens and the common good. Second is a distrust of government powers, wherein stewardship cannot be entrusted to the polity. “Privacy” in the Privacy Act is not a positive right, but rather a necessary provision subservient to limiting government powers.

Earlier in this study it was noted that HIPAA was passed to enable job mobility and GLBA was passed to modernize the financial services industry. Again, in the context of these laws, privacy is secondary to another purpose. In HIPAA and GLBA, privacy is a means to an end; in other words, privacy plays a functional or instrumental role. Society needs privacy because citizens need job mobility; society needs privacy to modernize financial services. Implicit is the message that if citizens did not need job mobility or financial services modernization they would not need to concern themselves with privacy. Even though privacy was cast as a functional need in both HIPAA and GLBA, the similarity ends there. These industry sectors have significantly different regulatory frameworks (Congressional Research Service, 2008). The security and privacy provisions in these laws are more reflective of the larger regulatory framework for these industries. The regulatory framework for these industries served as additional rules-in-use, shaping these laws.

Informational Regulation.

Another phenomenon that is essential to understanding the U.S. data breach laws is informational regulation. Informational regulation has become a striking development in American law (Sunstein, 2006). To date, informational regulation has applied in the environmental and health policy arenas. It is

noteworthy that informational regulation has been applied to these areas. In the case of environmental policy, informational regulations have protected aspects of the environment that are common (or public) good in nature, which by definition means that the private sector will not attend to them. A similar situation occurs in the area of public health, in which the health of all citizens is both good for the individual as well as for the collective as a means and an end, i.e., it is a common or public good.

Informational regulation has two functions. First, it serves to inform people of potential risk exposure (Volokh, 2002) and serves as “sunlight,” which was already discussed as the value of transparency. Second, informational regulation aims to change the behavior of risk creators (Volokh, 2002) and to exert pressure on entities to care for the common good. Informational regulation is useful in a polycentric policy arena in which the problems that the policy means to address are attributable to multiple sources, the solutions require participation from multiple parties, and the nature of problems and solutions is dynamic – all of which necessitate that the policy must allow for adaptability. Clearly caring for the environment or health are polycentric policy areas. Environmental and health problems stem from multiple sources, and ameliorating these types of problems takes ongoing involvement from multiple parties. The same is true for data security, identity protection, and privacy. Improved data security is possible only under conditions that shape the practices of numerous individuals and covered entities; therefore, policy that provides incentives for such change is, in theory, necessary. How does informational regulation work in practice?

Figure 5-2 shows the mechanistic view of the premise for informational regulation for data breach disclosure laws. Informational regulation intends to provide warning information to consumers. In theory, by enhancing the knowledge level, consumers can perform a personalized risk assessment and make purchase decisions based on that assessment. The market decisions made by consumers intend to drive the less secure entities out of the market, thereby improving the state of security overtime. In addition, the enhanced knowledge levels will propel consumers to engage in other protective actions, such as active credit monitoring or a credit freeze. Consumer credit monitoring typically includes alerting the bank and credit card merchant, notifying the FTC, and/or contacting law enforcement. A credit freeze allows consumers to lock their consumer credit report and scores. Once consumers have locked their credit information, the lender or merchant cannot access it, which significantly lowers the likelihood that the merchant will issue credit. The benefit is that the thief is not likely to get credit in the consumer's name (so the law prevents a false-positive, also called a Type II error). The downside is that this locking also impedes consumers from quickly getting credit in their name (a false-negative, or Type I error); note that consumers can release the freeze, but it takes a few days and may jeopardize quick access to special loans and other purchase incentives. These proactive consumer measures will in theory also lead to improved security over time.

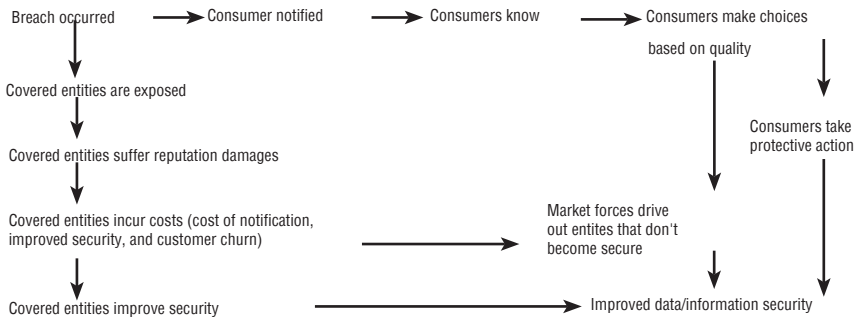


Figure 5-2. Informational Regulation Premise for Data Breach Disclosure Laws.

Informational regulation also aims to change the actions of producers. By engaging producers in providing information, informational regulation, in theory, reveals an entity's practices. This sends a signal to society that perhaps this entity cannot be trusted. The premise is that covered entities value their reputations. As such, they will act to improve their security in order to preserve their reputations and minimize associated costs, which could include the costs of the notification itself, as well as downtime costs, the costs of remediation and recovery due to the breach, and the costs of lost business. Ideally, these two streams combine to improve data security, which in turn mitigates ID theft and enhanced privacy.

The premise of informational regulation is that: 1) market mechanisms can shape risk behavior, thereby reducing the need for command-and-control regulations; and, 2) informational regulation enhances democratic processes and promotes individual autonomy. By providing data breach information to victims, in-

dividuals are empowered to make decisions based on quality (i.e., they can elect to purchase goods/services from a provider who offers enhanced information security and privacy), and market mechanisms will be fortified. A failure to provide complete and accurate market information can impede the efficient allocation of goods and services and result in market failure, which is the driver for changing producers' behavior.

In theory, informational regulation allows more public monitoring of decisions, a norm already discussed. By forcing disclosure, more people are informed; and by informing more people, the quality and the quantity of public deliberation will improve, thereby enhancing the democratic processes that are vital for openness and transparency. In general, information disclosure rests on the normative belief that citizens have a right to know the risks to which they are exposed. This information promotes choice and autonomy, both of which are foundational to what some may consider the penultimate norm in American society – liberty (Renshaw, 2002).

In contrast to command-and-control regulation in which the government sets and enforces standards, informational regulation is often less expensive. The United States values efficient government, and recent decades have seen an increased emphasis on downsizing the federal government. While it is not clear that command and control legislation would be effective in mitigating data breaches or in making data breach disclosure more effective, it is clear that a command and control approach is not politically efficacious at this point in time.

In summary, informational regulation has grown in areas where consumer protection, private sector practices, and risk converge. Examples include warn-

ing labels regarding mercury levels, nutrition labels disclosing fat content, and notifications about the side effects of a given medication. That data security shares these same material features—consumer protection, private sector practices, and risk—has clearly contributed to adopting informational regulation as the model for data breach disclosure laws.

Infancy of the Information Industry and Federalism.

Continuing with a thread that was started earlier—relative inexperience with the information age—the information industry includes: 1) industries that buy and sell information as a good or service; 2) certain service sectors that are especially information intensive, such as banking and legal services; 3) information dissemination sectors, such as telecommunications and broadcasting; and, 4) producers of information processing devices, such as computers and software. The information industry is a boon to the economy, as information amplifies growth in more traditional industry sectors, and the demand for information goods and services increases markedly. Because of the ends and means nature of information goods and services, the market is quite large and still emerging.

An example of emergence is the following relatively recent cascade of events: the Internet explosion; September 11, 2001; and the subsequent war on terror. These events converged to boost the data brokerage industry. Data brokerages are companies that collect and sell billions of private and public records containing individuals' personal information. Many of these companies also provide products and services, including identity verification, background screen-

ing, risk assessments, individual digital dossiers, and tools for analyzing data. Most data brokers sell data that they collect from public records (e.g., driver's license records, vehicle registration records, criminal records, voter registration records, property records, and occupational licensing records) or from warranty cards, credit applications, etc. In addition, data brokers purchase so-called "credit headers" from credit reporting agencies. Information on a credit header generally includes a person's Social Security number, address, phone numbers, and birth date (Congressional Research Service, 2007). Although some of the products and services provided by data brokers are currently subject to privacy and security protections aimed at credit reporting agencies and the financial industry under the Fair Credit Reporting Act (1971) and GLBA (1999), many are not. Because the industry is relatively young, there is no history of oversight or self-regulation of the industry's practices, including the accuracy and handling of sensitive data, by an industry-sanctioned body.

Data brokerages are not the only unregulated entities. There are many other organizations that process, store, and transmit personal information: state and local agencies, public hospitals, departments of revenue and motor vehicles, courts at the state and local level, agencies that oversee elections, K-12 schools, school districts, post-secondary institutions, and business entities engaging in inter- and intrastate commerce. Most of these entities are not covered by HIPAA and GLBA (Congressional Budget Office, 2006) and have traditionally been governed through state law; hence, the 46 state data breach laws discussed earlier. The suite of laws are in part a result of lack of experience with information markets, and are partly a function of the

need for legislation that spans the numerous and varied types of entities that process, store, and transmit personal information. A broad and amorphous social challenge such as information security and privacy is not only diffuse; it is emergent. Research has shown that in cases of open access, common good resources (such as security and privacy), collective choice action arenas, i.e., those that improve opportunities for communication and public deliberation, result in better joint outcomes (Ostrom, 1999). The patchwork of data breach laws fit this profile—they aim to increase communication and public deliberation.

In a federalist system, such as the United States, sovereignty is constitutionally divided between the federal government and the constituent states. The powers granted to the U.S. federal government are limited to the right to levy taxes, declare war, and regulate interstate and foreign commerce. The powers traditionally reserved by the states include public safety, public education, public health, transportation, and infrastructure. Of course, information security and privacy challenges permeate these state-governed organizations, too. While a federal preemptive law might span all organizations and individuals, there is the possibility that it would erode state sovereignty and, in the process, alter the federal-state balance of power in unprecedented ways. The patchwork suite of laws that we have can be partially attributed to a collective belief that this is wrong. This retrospective analysis provided nuanced insight into the present. Federal laws were enacted to delimit government powers, and privacy seemed necessary for that purpose. Private industry sector laws were passed to protect the private sector, and data security and privacy were functional means to that end. These federal and

private sector laws reflect a general U.S. cultural norm of distrusting government while trusting in the private sector and market forces. Informational regulation was established as a form of legislation considered effective for issues that spanned consumer protection and risk, and where market mechanisms would/could work effectively, which is further evidence of pervasive trust in the private sector.

LOOKING FORWARD

Technological advancements are changing the information security and privacy landscape considerably; in response, organizations grapple to enact social controls, i.e., public policies, that mitigate the ill effects. Yet, these policies are blunt instruments not suited to the careful excision of these ills. As mentioned earlier, some critics contend that the nation is drowning under a myriad of different state data breach notification laws and argue for a preemptive federal data breach notification law. Others contend that the current laws can suffice if modifications are passed.

Some advocates of modifying existing laws assert that the outcome of data breach disclosure should be to motivate large-scale reporting so that data breaches and trends can be aggregated, which allows a more purposeful and defensive use of incident data. Those who advocate for large-scale data collection view the existing laws as “disclosure disincentives” for two reasons: 1) breached entities view themselves as victims of attack and not deserving of reputational repercussions; and, 2) existing laws offer covered entities considerable discretion as to whether to disclose. Together, these factors result in underreporting of data breaches, which in turn constrains large-scale data

collection regarding breaches. The proposed policy solution is to modify the laws to make breach notification completely anonymous where breached entities report to an intermediary and not to consumers.

Whereas others who advocate for modifying the existing laws suggest coordinated response architecture (CRA) (Schwartz and Janger, 2007), supporters of this alternative agree that large-scale data collection on data breaches is necessary, but contend that consumer notification needs to be amended, not eliminated. Their main concerns with the existing consumer notification practices are that: 1) there are too many notifications, leading to consumer desensitization; and, 2) the information provided to consumers is unhelpful at best and befuddling at worst. In response, this group advocates for amendments to the data breach laws to include a CRA. The CRA is an intermediary agency with responsibility for: 1) supervised delegation of the decision whether to give notice; 2) coordination and targeting of notices to other institutions and to customers; and, 3) improving the content of notices sent to consumers.

Each of the alternatives offers a critique of the existing suite of laws. Each critique is grounded in a premise of what outcomes matter, and each alternative offers a view on how policy can/should target actions in pursuit of these outcomes. Questions of what should be with regard to ID theft, privacy, and security remain salient. The problem is both highly polycentric and emergent, and these conditions favor polycentric and incremental policy approaches.

Yet, others would suggest that informational regulation is the wrong type of legislation entirely, and that tort law would be more effective for redressing problems of negligent behavior. Still others support

a mix-and-match set of policy alternatives. One example is a preemptive federal law in conjunction with tort laws and existing state laws, in which the scope of preemption is fairly narrow. The justification is that such a policy mix would allow greater stringency, and therein sovereignty, in state laws as desired by states, but provide for certain requirements in a federal law in areas that are crucial to improving security.

As opposed to thinking about discrete policy solutions, challenges in information security and privacy are highly polycentric and emergent; these conditions in turn favor polycentric and incremental policy approaches. The 46 state data breach laws put data security into the hands of citizens and organizations. In a society pillared by equity and freedom as ideals, where there is no constitutional provision for privacy, the constant for deliberating the common good is through an open and representative process. This myriad of data security laws aim to serve the purpose of making explicit these individual preferences in a manner that allows all to translate these preferences into collective choice—the future of data security is contingent on seeing more laws enacted to address facets of information security and privacy, and second, that these laws are likely to be more polycentric, not less.

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CHAPTER 6

CYBER SECURITY AND IDENTITY: SOLUTIONS FOR CRITICAL INFRASTRUCTURE THAT PROTECT CIVIL LIBERTIES AND ENHANCE SECURITY

Joshua Gruenspecht

INTRODUCTION: IDENTITY PROBLEMS AND IDENTITY VALUES

Problems with identity determination raise some of the most complicated and unresolved issues in cyber security. Just as in the physical world, identity online can be crucial both in restricting access to critical resources and in responding appropriately to threats or attacks. In the networked world, however, identifying a communications partner can be difficult, and information security can suffer as a result. Industry and government are pursuing a number of approaches to better identify communicants so as to secure information and other assets. As part of this process, some policymakers have suggested fundamental changes to the way in which the Internet transmits identity information. Though their solutions have varied, this subset of policymakers has coalesced around the general idea that Internet communication needs to be more traceable so that malefactors can be tracked more easily.

What these policymakers often fail to recognize is that identity is bigger than cyber security alone. Changes to online identity standards may also have effects on civil liberties and global freedom, economic and technological innovation, market choices,

consumer privacy, and other issues associated with online business models. Authentication mechanisms that do not consider commercial compatibility may be left behind in the marketplace, while enforced compatibility may create barriers to entry for entrepreneurs. Mechanisms mandated by the government, though, may choke off superior private-sector solutions. Enhanced identity mechanisms may complicate the right to anonymous speech and increase the ability of repressive regimes to target dissenters. In all these ways, network identity is not just a matter of security, but also a matter of civil and economic freedom. Accordingly, the development and implementation of identity solutions must involve a weighing of values.¹ Increasing the traceability of communications endangers many of these values. Instead of expending limited resources to pursue solutions that have serious negative consequences, it is incumbent upon policymakers to first consider alternative ways to address the cyber security identity problem.

In order to assess the full spectrum of identity solutions proposed for cyber security, it is useful to understand that there are two related but distinct sets of problems in network identification: authentication and attribution. Authentication refers to the process of verifying the identity of a communicant (a machine or a user). Where an identity is associated with certain permissions, authentication mechanisms can be used to protect critical resources by securing systems from unauthorized access. Attribution, in contrast, concerns questions of how to determine the identity of a communicant (as the source of certain code or other data) based on all of the information that the communicant has placed onto the network, including metadata associated with his or her communications. Attribution

strategies can help assign responsibility for an attack. They can also help identify threats to network security, thus helping to mitigate those threats before their impact is felt. In some scenarios, authentication information can play a significant role in attribution, though often policymakers gloss over this piece of the attribution equation.

The first section considers both sets of problems and concludes that authentication-oriented solutions are more likely to provide significant security benefits and less likely to produce undesirable economic and civil liberties consequences. The second section explains the concepts of authentication and attribution in greater depth, discussing how each relates to network security and to other core values. The third section explains how identity information is currently exchanged on the Internet, and what authentication and attribution challenges are raised by these existing solutions. The fourth section evaluates proposed solutions to identity problems and the policy issues associated with those solutions, explaining the benefits and drawbacks of each for both cyber security and for other values. The last section provides conclusions reached as a result of this analysis.

AUTHENTICATION AND ATTRIBUTION: IDENTIFYING THE COMMUNICANT

Authentication: Demanding Identity Before a Transaction.

Authentication is “the process of establishing an understood level of confidence that an identifier refers to a particular individual or identity.”² Authentication often involves an exchange of information be-

fore some other transaction in order to ensure—to the extent necessary for the transaction at hand—that the sender of a stream of traffic is who he or she claims to be or otherwise has the attributes required to engage in the given transaction.³ Enhancing the security of the authentication process in turn enhances the security of the transaction. Because critical resources such as utility control systems, financial networks, and systems holding classified information are increasingly accessible through the Internet, authenticating users becomes an important cyber security concern. There are two sets of authentication questions that drive security. First, how can authentication security be improved? Second, what level of authentication should be required in any particular situation?

To understand how improvements happen, it is important to understand the underlying authentication transaction. There are three parties to an authentication transaction.⁴ The “user” associates him or herself with a digital identity; the “identity provider” facilitates and stores that association; and the “relying party” asks the identity provider to verify the user at the time of the transaction (or relies on something provided to the user by the identity provider). In many situations, the identity provider and the relying party are one and the same (e.g., a business issuing user names and passwords for access to its own internal network, or Google authenticating a user into Gmail). Combining the two can increase security by reducing both the number of parties to the transaction and the technological complexity of the transaction, but it can also reduce security because, when every relying party issues its own identities, users (even sophisticated ones at important facilities) engage in insecure practices.⁵

Information exchanged to authenticate identity is often broken down into three separate classes of authenticators: something you know, such as a password; something you have, such as a card or USB token; and something you are, such as biometric information.⁶ Including multiple factors, especially from different classes, generally increases the security of the transaction.

Creating a digital identity generally requires some form of “proofing,” a pre-authentication step in which the user and the identity provider exchange other authenticators. This process sometimes involves off-line identities and sometimes involves, especially for higher levels of security, an in-person interaction. If the authenticators used to prove identity are themselves invalid, or the proofing process is otherwise inadequate, the resulting identity credentials will not be reliable.

Underlying the second question, “What level of authentication should be required?” is the supposition that different kinds of transactions should require different levels of authentication. Some observers believe that certain online transactions, for example, accessing a publicly available government website, can be permitted with no authentication, while others propose that at least some identification should be part of every Internet transaction.⁷ Although, almost all technical solutions and policy proposals involving identity are based on the creation of levels of assurance (LOAs).⁸ LOAs rank networked systems according to the consequences of authentication failure and define authentication requirements at each level. Accessing a newspaper article, for example, surely requires fewer assurances of identity than accessing the control system of a nuclear reactor. Work has already been done to define LOAs for federal systems,⁹ and private sector

identity initiatives have followed the government's four-level framework.¹⁰ However, what is lacking, certainly in the private sector, is any agreement on what level of assurance is required for what type of transaction or access. To the extent that this lack of agreement leaves critical resources inadequately protected raises significant cyber security concerns as to why there has been a failure to adopt standard LOAs.

To some degree, cyber security identity may benefit from developments in the e-commerce and social networking sectors, where identity and authentication are hot topics. Online service providers recognize that users dislike the complexity of maintaining multiple identities, and therefore providers want to streamline their identity processes. At the same time, advertisers and advertising platforms see huge benefit from linking online activity with offline or true name identity.¹¹ As a result, multiparty efforts are underway to create identification systems that will work across sites,¹² and individual companies such as Facebook are stepping forward as universal commercial identity providers.¹³ Combining these efforts with cyber security efforts might have beneficial network effects such as the reduction of complexity. However, these commercial solutions are not likely to have the proofing mechanisms or implementation security required to serve at high LOAs.

Finally, authentication solution designers in the commercial context have to take into account user expectations, since users may abandon services that fail to protect anonymity when users consider it integral to their use of the service.¹⁴ Attempts to apply cyber security authentication solutions at lower LOAs may face similar resistance.¹⁵

Attribution: Determining Identity after a Transaction.

Attribution is the analysis of information associated with a transaction or series of transactions to try to determine the identity of a sender of a stream of traffic. Information collection and analysis is the focus of attribution. Transaction design is also relevant to the extent that it can help assure the availability of information to analyze.

The absence of an easy means of identifying the originator of malicious traffic gives rise to security policy concerns at multiple levels.¹⁶ First, on a practical level, the recipient of unwanted traffic is more limited in its ability to respond to the problem if it cannot identify the sender of that traffic. That recipient may restrict further traffic from a given network source, for example, but will have to regroup if the sender re-routes his or her traffic. Second, as a matter of tort and criminal law, it is difficult to construct a legal case against a virtual interloper without attribution.

Third, as a matter of international law, the laws of war demand both proportionality of response and minimization of damage to the property of non-aggressors and neutral third parties. Even if there were a legal understanding of what actions constituted “cyber war,” the use of military force would be impermissible under international law without the ability to determine the identity of the aggressor. Relatedly, an attribution deficit reduces the effectiveness of deterrence as a policy for discouraging bad actors, whether criminal or governmental. American foreign policy relies heavily on deterrence in other warfighting spaces. In cyberspace, a lack of attribution may handicap that reliance.¹⁷

Because attribution is a forensic discipline, the key problems revolve around the availability, collection, and analysis of information. There are multiple kinds of relevant information. Both the malicious code itself and associated communications metadata can offer hints as to the identity of the sender. Traffic routing information can help trace communications back to their starting point. Background intelligence can help contextualize transactional information.

Traffic routing information is particularly important to attribution. Meticulous attention to content can often remove traces of identity, but no sender can escape the fundamental truth of routing: content has to be sent from somewhere. As we discuss below, Internet protocol (IP) addresses are a useful source of identity information. However, some policymakers argue that Internet transactions do not offer enough information about routing and that changes in routing systems and/or networks must produce additional information for attribution.¹⁸ Other experts warn, however, that network-level personal attribution is of limited forensic value. David D. Clarke and Susan Landau, for example, argue that, rather than issuing calls for better attribution on the network, applications should be designed that do a better job of integrating identity and attribution when and only when it is actually necessary.¹⁹

Increasing the ease of attribution may have unintended consequences. Re-engineering traffic routing for all Internet transactions will challenge privacy and anonymity, including in situations in which privacy and anonymity are in the best interests of the United States and other democratic countries.²⁰ In contrast, some regimes have demonstrated an interest in using Internet attribution as a means of controlling dis-

sidents' access to information online.²¹ In addition, if attribution solutions require Internet service providers to invest more heavily in specialized hardware or software, they may indirectly raise barriers to entry for new Internet services. Increasing attribution may also substantially affect policy efforts aimed at giving consumers greater control over the compilation of online profiles.²² Weighing these consequences against the cyber security benefits is a critical task for policymakers.

Authorization and Auditing: Security Issues beyond Authentication and Attribution.

Although this chapter focuses on authentication and attribution, two other issues closely relate to identity and are critical elements of any secure system: authorization and auditing. Authorization is the process by which a given authenticated user identity is associated with a set of permissions. Authorization mechanisms are used, for example, to prevent the use of low-security accounts to access high-security information and controls. Policy interventions aimed at improving the technical security of authentication should not ignore the security of authorization mechanisms. Indeed, measures to improve authorization may offer some of the greatest benefits to cyber security at the least cost to other values.

Auditing, meanwhile, refers to two processes. The first consists of reviewing a system periodically to ensure that it continues to function properly. The second consists of reviewing a system after it fails to determine what caused that failure. Keeping adequate system logs and reviewing such logs regularly and thoroughly is a critical security function. Unless sys-

tems are audited, many compromises will never be discovered or will not be discovered until it is too late.

Though both authorization and auditing are important, authentication and attribution pose especially thorny policy questions and have been the focus of much recent debate. Accordingly, this chapter focuses on authentication and attribution as the key policy problems, although further examination of authorization and auditing is certainly justified.

IDENTITY AND THE INTERNET: HOW AUTHENTICATION AND ATTRIBUTION WORK IN PRACTICE, AND WHAT CONCERNS CURRENT SOLUTIONS RAISE

Identity on the Internet: How Parties Exchange Identity Information, and What Information They Exchange.

The Internet is a physical network of interconnected hardware devices. Each device uses the same suite of protocols, including the IP, to communicate. To forward data, the network of data connections between those physical devices relies on IP addresses—“logical” addresses—rather than any information about physical device type or location. This offers several benefits. One is that the individual networks that make up the Internet can interoperate without each one having to maintain an exhaustive list of the physical location of every communications partner on the Internet. Instead, routing protocols allow networks to determine which logical neighbor is closest to the destination, and to pass data along to that device. Not until the last step does the recipient’s physical location matter. Another benefit is that physical devices of all

kinds can join the Internet without having to adhere to a particular hardware specification. As long as a device can run the protocols, it can exchange data with other devices.

IP addresses are a key source of identity information exchanged with every Internet packet. As IP addresses are logical, not physical, they are not permanently tied to any particular user or machine. However, they do provide useful identity signifiers. Blocks of addresses are generally assigned to businesses and Internet service providers (ISPs) and then leased to individual users.²³ On its own, an IP address can often identify the country of origin and, depending on how the owner of a block assigns addresses, perhaps a region, a city or neighborhood, or even a particular location. Moreover, at any given moment, every IP address in use is known by the ISP to be linked to a particular device or a particular physical address, which can be determined with the cooperation of the Internet service provider. Though the ISP may not always be able to map an IP address directly to an end-user device (e.g., when a user is connecting through a wireless router), it can point an investigator in the right direction. As a result, IP addresses can be very useful in locating the origin of traffic.

The IP suite also requires that additional routing information be exchanged in Internet transactions. While this information does not relate directly to the identity of the transaction partners, it can be indirectly useful in identifying a sender. For example, packets contain a “time to live” (TTL) field, which counts down the number of routing hops that the packet has taken from source to destination. The TTL field can sometimes be useful in helping to determine how distant the originator of a given stream of traffic is from his or her target.

The last type of information contained within almost all Internet packets is content, which can also be useful in attribution. Individual packets of information may bear hallmarks of their origin or traces of data from their sender. Natural language contents may be written in a particular foreign language or show evidence of having been written using a language-specific keyboard layout. Exploits and other forms of malicious code may contain stylistic signatures associated with a particular user or group. Analysis of such content, however, is inevitably ad hoc.

Aside from these general sources of identifying information available within all Internet traffic streams, there are also information sources specific to authenticated transactions. For example, many online services require their users to authenticate themselves, which often provides a reliable means of identifying communicants. Generally, commercial services design their own authentication protocols. Given the many classes of services that require authentication—financial institutions, merchants, and so on—there are many different authentication protocols. The most common authentication paradigm for services involves setting up an encrypted connection to the user using a one-time key, requesting authenticators²⁴ from that user to establish identity, and then allowing the authenticated user access to the service.

Authentication may be performed by a third party (the issuing party), with credentials subsequently passed to the service provider (the relying party), or the service provider may perform the authentication itself.²⁵ In the first case (the “triangle model”), the relying party redirects the user login to the issuing party, which authenticates the user and then returns a token establishing the user’s credentials to use the service

provider site. One example of the triangle model is Facebook Connect, a service allowing users to leverage their Facebook identifications (IDs) to log into other sites. More sophisticated issuing parties may even handle authorization, returning a token that not only authenticates, but also specifies which services a user may use. In the second case, the service provider handles the authentication and authorization directly. An example of this bilateral model would be Apple's web services, which require that users establish accounts directly with Apple, and then authenticate directly to Apple itself.

Entities that rely on identities issued by others possess the local account ID of the user—perhaps a real name, perhaps not—but not information about additional authenticators, such as passwords or information obtained through proofing. The issuing party possesses that latter information. Service providers who use the bilateral model have all the information collected during both the initial proofing step and the authentication step.

Cyber Security Concerns: Problems with Existing Exchanges and Areas of Possible Policy Intervention.

Authentication Concerns.

Critical infrastructure is lagging in the adoption of secure authentication,²⁶ but this does not seem to be due to any technological issues. There appears to be general consensus that the available technological means of authentication are sufficiently secure to protect information.²⁷ Under that assumption, then, the most important policy issues in authentication

are ensuring that, first, critical infrastructure appropriately adopts these technologies and, second, that critical infrastructure authorities properly implement these technologies to minimize the possibility of compromise from human error. Adoption within critical infrastructure may be slowed by the lack of product metrics, the absence of agreement on what level of assurance is appropriate for a given context, the dearth of information about cyber security risks and their costs, and poorly designed incentives for the adoption of improvements. Fundamental ease-of-use problems with identity technologies also exist, which may require additional innovation.

One barrier to adoption may be the absence of metrics surrounding the use of authentication technologies. The average system administrator may not understand the relative merits of one technology or product over another. Product metrics that made comparison across technologies or products simpler could improve the ability of information technology (IT) professionals to understand tradeoffs.

A second adoption barrier may be the absence of recognized levels of assurance for any given level of access or permission. Does a utility control system require more protection than a bank? Do different banking systems or functions require different levels of protection? If businesses knew which LOA was appropriate for a given system or function, they would have a common language with which to decide what level of security is appropriate. In turn, those levels of assurance can help make the creation of metrics easier as well, by allowing product security ratings to refer to LOAs.²⁸ To address these concerns, further work could be done to define appropriate LOAs for different private sector systems. In particular, LOAs that

are more granular than the existing four-level government LOAs might help to speed adoption, given that security needs have many different dimensions across the full range of American industry.

A third potential barrier to adoption of authentication technologies is part of a broader cyber security concern: information sharing. Owners and users of information infrastructure may not understand their own vulnerabilities.²⁹ Without additional information connecting security failures with their ultimate costs, companies are unlikely to invest in better cyber security, and, by extension, better authentication mechanisms.

Finally, even with better information, institutions may not have proper incentives to invest in measures, such as better authentication, that improve cyber security. Some contend that cyber security is a public good and that the private sector may routinely under-spend: the costs of security expenditures go directly to the bottom line, but the economic consequences of breaches are diffuse.³⁰ Under this theory, unless more of the costs of security failures transfer to the institutions that fail to invest in security, adoption of authentication technologies will continue to lag.

Convincing critical infrastructure to adopt appropriate authentication measures is only part of the battle for better authentication. The designers of authentication products also need to focus on making those measures easy to use without reducing their effectiveness. Flaws in protocols and software implementations are sometimes used to foil authentication mechanisms, and authentication manufacturers, like all software manufacturers, need to address those issues as they arise. However, the bigger threat comes from user error. Through the misappropriation of authenticators,

malicious actors can gain access to resources they are otherwise unauthorized to use. This information is often exposed by the weakest link in the authentication chain: the individual user.

One way to address this problem might be to increase the interoperability of credentials. When users have a need to access dozens of online retailers and remote servers, each with its own authentication mechanism, the obvious temptation is to create mnemonics: either to duplicate authenticators across providers (e.g., use the same username and password in multiple places) or to store authenticators in an easily accessible location (e.g., put passwords in a text file on a user's desktop).³¹ Such mnemonic solutions weaken the strength of authentication measures. If malicious actors can steal lists of authenticators from systems with weak protections or pull a stored list of authenticators off a user machine, they can use the authenticators to compromise a high-security target. It is easier to avoid mnemonics when a user authenticates to a single identity provider, and that provider in turn offers the user's credentials to each relying party. On the other hand, the compromise of an authenticator used across multiple services can have widespread consequences. Too much centralization can be as dangerous as too little. As noted above, the commercial identities most likely to develop toward interoperability are unlikely to be useful in truly sensitive contexts. It is important, therefore, that interoperable systems intended to address these problems are implemented properly: technically secure, privacy-protective, and with appropriate provisions for multiple providers and for anonymous and pseudonymous identification at low LOAs.³²

The most important ease of use concern, however, may be reducing the possibility of compromise through social engineering and other forms of intelligence collection. Social engineering—the act of manipulating users into turning over confidential information such as authenticators—is a key component of many attacks on authentication mechanisms. By socially engineering users or otherwise collecting information on those users, malicious actors obtain or recreate those users’ authenticators without having to crack the authentication system itself. Striking the proper balance between usability and security is a key part of ensuring that authentication measures provide the expected amount of security.³³

Attribution Concerns.

Even though IP addresses can help to determine physical location in many cases, they often fail to map traffic to a physical identity. Moreover, malicious actors have developed techniques that allow them to obscure their logical identity when sending traffic to a target. Such techniques include identity-stripping, multistage attacks, and multistep attacks.³⁴ In order to battle these techniques, attributors would need additional information. This information could come from two sources: the collection and sharing of existing information between networks on the larger Internet, and the creation and collection of additional information connecting both logical and physical identities to incoming traffic.

Although IP addresses can be helpful in narrowing down a communicant’s location, an Internet-facing IP address does not easily map to a particular user. In various situations, users connect to the Internet

through systems using Network Address Translation (NAT). Such systems pool traffic on an internal network and stream it out to the Internet using a single Internet-facing IP address. These systems may or may not retain a history of the devices that used the service. Users can also move from local system to local system while continuing to communicate with a traffic recipient, which provides another way to change their IP addresses. Even when records from the right location at the right time can be found, they are likely to map only to a physical hardware address, not a physical user identity.³⁵

Sophisticated malicious actors take steps to make attribution through logical addresses even more difficult. When a given attack does not depend on two-way communication, as when a malicious actor attempts to shut down a system by flooding it with traffic (a distributed denial of service attack [DDoS]), that sender may work to remove IP addresses from incoming packets to stymie efforts at attribution. At that point, attributors must trace step-by-step back through packet logs that may or may not exist, and that are often not on machines controlled by the recipient, in order to find the packets' origin.

Even when an attack does require two-way communication, a sender may disguise his logical identity in other ways. Multistage attacks, for example, route through large numbers of servers and/or through networks of compromised computers (botnets). By issuing commands with several intermediate recipients between source and destination, the controller again requires a prospective attributor to trace control information back through those routes. That path will likely include machines that are not part of the recipient's network and that are beyond the easy reach of investigators in the country where the recipi-

ent resides. Many multistage attacks also take place in several temporally distinct steps. In other words, over a long period of time, individual machines may be compromised, and the resident malicious software will lie dormant until activated by a controller. Such multistep attacks can make finding the original sender even more difficult, because information required to trace the traffic back to its origin may not have been retained.

These malicious techniques rely on the proposition that tracing traffic through multiple networks is difficult. One possible policy intervention, then, is to increase the ease with which data are shared between networks and between machine owners. However, the number of entities that potentially hold relevant routing data is very large, consisting of essentially every computer connected to the Internet. Creating a trusted network for information sharing even just among the community of ISPs has not proven feasible yet, especially when service providers are in different countries. “[C]ooperation among institutions that possess this data has been slow to emerge” for a number of reasons.³⁶

As with the slow adoption of authentication mechanisms, incentives may be part of the problem.³⁷ Those who possess relevant data may not suffer enough direct damage to make information sharing a priority. Legal barriers to information sharing between ISPs may also play a role. ISPs may fear that sharing such information will run afoul of federal laws on the privacy of communications data.³⁸ Cautious legal counsel may advise against testing the boundaries of the law. Finally, there may also be technical barriers. Some routers may not currently possess the capabilities required to store traffic information for a significant

length of time, or to perform more advanced monitoring of traffic.

Once domestic barriers are addressed, the more challenging problem of sharing traffic information across international borders remains. Law enforcement agencies such as the Federal Bureau of Investigation (FBI) do work across borders to track cybercriminals, and several Western nations have ratified the Budapest Convention, a framework for sharing information related to online crime.³⁹ However, attempts to create a legal framework that reaches more countries and covers a wider range of cyber security incidents have not progressed.⁴⁰ Cyber attacks cross and re-cross borders before reaching their targets. So long as some nations fall outside the network of cooperation, attribution may not be able to proceed further than determining a country of origin.

Going beyond attempts to increase information exchanges, policies could also attempt to create entirely new information trails. The simplest means of doing so would be to implement some of the authentication-oriented changes discussed in the previous section. Attribution is only possible where there is information to audit; instituting new and stronger authentication and authorization mechanisms with associated auditing capabilities and deploying them to critical systems creates that information. Building attribution capabilities into authentication systems is part of the classic network identity and security paradigm known as authentication, authorization, and accountability (AAA).⁴¹ Computer security experts use authentication mechanisms to establish the acceptability of an identity and authorization mechanisms to associate it with actions. Then, through an accounting and logging system, these mechanisms provide records for

investigators to retroactively check that identity's use of the system – in other words, to attribute actions.

More fundamental technological changes might include generating more information about traffic as part of the routing process, linking logical identity more tightly to traffic, and even tying physical identity to logical identity through some sort of registration process. All of these methods would create at least some additional information useful to attributors, but the barriers to uniform global cooperation are very high, and the associated technologies could also be subverted by sophisticated malicious actors. Putting such changes into place, though, would also have moderate-to-severe consequences.

PROPOSED SOLUTIONS TO CYBER SECURITY IDENTITY PROBLEMS: WEIGHING THE OPTIONS

Suggestions for solving cyber security identity problems are numerous. This final section lays out some proposals that have been raised in various legislative, technical, and diplomatic forums: first those aimed at authentication issues and then those aimed at attribution issues. This section briefly discusses some of the strengths and weaknesses of each proposal and also sheds light upon any significant effects that policy interventions may have in areas beyond cyber security. Ultimately, the section concludes that authentication-oriented proposals are more likely to create substantial security benefits and less likely to result in undesirable consequences for other values than attribution-oriented proposals, and that policymakers should strongly consider less coercive means of increasing the uptake of successful authentication technologies before turning to regulatory solutions.⁴²

Authentication-Related Policy Proposals.

- **Specify or improve cyber security standards, levels of assurance for private-sector systems, and/or metrics for authorization products.** The creation, improvement, and adoption of security standards and metrics for both systems and products can help prioritize the deployment of strong authentication where it is most needed. Such standards could be developed through various processes, involving more or less governmental involvement, and their adoption could be promoted by a variety of means. The White House has suggested that a federally guided process for developing LOAs and metrics would help fill important gaps.⁴³

Without prioritization, any movement toward greater authentication could be chaotic, so better-defined LOAs and metrics would help focus efforts toward securing critical infrastructure first. Ideally, standards and metrics would be industry-created, given the superior understanding of authentication system design in the private sector. Government-created standards or metrics run a risk of ossifying authentication system design because of their potential inflexibility. Given the information deficit in the private sector regarding the nature of the cyber security threat, however, government collaboration in standards design in some capacity seems appropriate.

- **Mandate authentication mechanisms for critical infrastructure.** It may not be sufficient to wait for owners to comply voluntarily with suggested government levels of assurance.⁴⁴ Multiple cyber security bills put forward in in a recent session of Congress considered the imposition of regulatory standards on critical infrastructure systems, authority that could encompass standards for authentication.⁴⁵

Regulation may be capable of pushing strong authentication standards onto critical infrastructure farther and faster than merely voluntary standards and LOAs, assuming that the designated regulator issues regulations in a timely manner and with sufficient specificity. At the same time, regulation in highly technical areas like information security can slow innovation and hold back the adoption of new and better security mechanisms. Moreover, before critical industries can be regulated, they must be defined; some of the recent bills are vague on what systems should be covered.⁴⁶

Separately, the mandating of authentication may stifle both innovation and free speech rights unless “critical infrastructure” is carefully delimited. While multifactor authentication may be desirable for some factories and power plants, it is inappropriate for the government to demand that many other networked systems, such as communications networks, authenticate their users. Anonymity is a core free speech value,⁴⁷ and maintaining the right to anonymity in online communication is critical to keeping that right vital in the digital age.

- **Increase the costs to various parties of breaches caused by the failure to take sufficient security measures.** Increasing the costs of an avoidable security failure to the responsible ISP, network service provider, security software provider, or system operator would increase those parties' willingness to take steps to improve authentication. Cost increases could come in the form of regulatory fines for breach or in tort damages to affected parties. Legal scholars have suggested various ways to shift cost.⁴⁸

As a practical matter, such approaches may be difficult to implement because of the complexities of determining causation in cyber security breach cases,⁴⁹ as well as the difficulties of defining a standard of care. These uncertainties, compounded by innate difficulties in predicting outcomes in the court system or in regulatory processes, may also cause innovation in security technologies to slow as service providers choose only those technologies that are court- or regulator-approved.

- **Enhance federal compatibility with commercial identity infrastructure.** It has been proposed that security in the consumer and e-government contexts could improve by enhancing the interoperability of identity. This is a major theme of the draft National Strategy for Trusted Identities in Cyberspace (NSTIC).⁵⁰

While the NSTIC is premised on the principle that the private sector should have the lead in the development of identities for access to online services, the federal gov-

ernment might be able to speed adoption of interoperable credentials by relying on commercially issued identities for authenticated transactions with government agencies. The White House strategy recognizes that over-centralization of identity data poses privacy risks. Among other things, identity providers could have a broad window into online behavior. The White House proposal calls for an identity ecosystem that would allow users to move freely between identity providers.⁵¹

Attribution-Related Policy Proposals.

- **Improve domestic sharing of cyber attack-related information.** Attack traceback is a critical component of attribution and of information-sharing facilitates that traceback. The sharing of cyber security information between ISPs and other network operators in the United States is thus an important step in malicious code analysis and attack prevention, not least because it pools information about attacks that can lead to attribution. The major service providers and network backbone providers already share some information, but have floated proposals that would allow them to share more.⁵²

Improving information sharing may require amendments to existing electronic privacy laws, and creating or expanding cyber security information-sharing exceptions will inevitably pose privacy concerns. Narrowly tailoring any new exception could help to minimize the impact on privacy.

- **Improve international sharing of cyber attack-related information.** Information sharing is especially important when international traffic is involved; sharing across borders is the only reliable way to attribute traffic to foreign end users. The Budapest Convention on Cybercrime recognizes this importance: of the seven articles that contain specific obligations for parties, six require cooperation in data retention and information sharing, and the seventh requires a 24-hour point of contact for data requests.⁵³ However, implementation to date has been limited; even between signatories, sharing is not swift or guaranteed.⁵⁴ Broader ratification of the convention and the adoption of a protocol giving more specificity to information-sharing obligations might help.

However, international information-sharing frameworks that are not carefully designed or do not include adequate standards risk both inadvertent or unjustified sharing of Americans' private data with overseas entities and the possibility that American companies may need to participate in enforcing foreign laws in contravention of U.S. foreign policy goals. Since a large percentage of the world's Internet traffic passes through the United States, a large share of the burden of improved information sharing might fall on U.S.-based service providers. In a larger national security framework, rules that guaranteed information sharing could undesirably tie American hands, given our reported advantages in cyber offense and cyber exploitation.⁵⁵

- **Institute IP traceback mechanisms on a voluntary or mandatory basis.** Some technological solutions to the attribution information deficit have been discussed. One set of solutions involves the implementation of IP traceback mechanisms, which require routers and/or other intermediaries between the sender and recipient of a stream of traffic to send signals periodically to the recipient. In theory, the recipient will ultimately hear from many points along the path that the traffic has traveled, which will assist in reconstructing the path from source to destination.

There have been a number of proposals for performing IP traceback without redesigning fundamental network protocols.⁵⁶ As of May 2008, a working group at the International Telecommunications Union (ITU) was attempting to create a unified IP traceback standard for telecommunications equipment manufacturers.⁵⁷ The intermediary use of ITU-standards-compliant routers is voluntary. A regulatory process for critical infrastructure, as proposed in some cyber security bills, could make it mandatory on a domestic basis but, as with other solutions requiring cross-border implementation, the problems of international adoption remain daunting. Also, IP traceback mechanisms beyond simple logging have seen only limited use in the real world. They may be highly effective or trivially avoidable.

To the extent that IP traceback is effective, it would provide a powerful tool to attributors. It will also present a barrier to the privacy

and anonymity of users vis-à-vis both governments and ISPs. While not as dangerous as full-on authentication for all communications networks, IP traceback still provides intermediaries with enough technical know-how a way to trace “undesirable” speech. This would be a powerful tool for governments interested in tracking and stifling dissenters.

For example, as the recent revolutions in Egypt and Libya demonstrated, the Internet is invaluable for organizing and for circumventing government control of other communications channels.⁵⁸ One critical component of dissidents’ online activities has been the use of tools designed to circumvent government surveillance, many of which are financed, in part, by the U.S. Government.⁵⁹ Traceback mechanisms threaten the use of those tools and the safety of those activists.

- **Readdress the Internet along geographical lines.** As the Internet moves from an older version of the IP (IPv4) to a newer one (IPv6), there may be an opportunity to map logical addresses more closely to physical addresses. The larger address space of IPv6 may make it easier to permanently associate some subset of physical devices with fixed logical addresses. It also provides a rare chance to reconsider the procedures for assigning addresses. At least one ITU proposal has suggested that IPv6 addresses be assigned along geographical lines.⁶⁰ Again, achieving consistent international implementation seems unlikely, especially when certain

government agencies themselves would likely resist being reliably identified.

Pinning logical addresses to devices and/or assigning them geographically would assist in attribution, although careful safeguards would have to be in place to avoid the falsification of addresses (spoofing). Any strong link between IP and physical devices might assist in the persistent tracking of the user of that device, even over multiple Internet sessions, which raises privacy and free speech concerns similar to those discussed in the previous section.

- **Engineer more identity information into packets.** Some technologists have also proposed redesigning the IP or other base protocols to carry more reliable identity information about the sender within each packet. The simplest proposals in this area merely attempt to alter routing information to make spoofing of logical addresses more difficult.⁶¹ Others add device-identifying signatures directly to each packet.⁶² Some policymakers have even implied that each packet should link to identity information about the user rather than that user's device, presumably through some sort of authentication mechanism.⁶³

Technologists argue that user-focused proposals, in particular, are only marginally helpful in solving attribution problems.⁶⁴ Both user- and device-oriented changes to IPs raise market action, innovation, and civil liberties issues. Only heavy subsidies or heavy regulation will persuade institutions

and individuals to give up their existing Internet devices. Any Internet-like network that has identity-storing gatekeepers is also a network with significantly higher barriers to entry for innovators, who may now need permission to operate their online services. Such a network would make anonymous speech much more difficult and sharply reduce online privacy.

After examining all of these proposals in the context of their security effects and their effects in other realms, it is clear that there are two major differences between the class of attribution-oriented proposals and the class of authentication-oriented proposals. First, the civil liberties impacts of many of the attribution-oriented proposals may be heavy—the technical proposals, in particular, impact privacy, free speech, and anonymity both at home and abroad—while the civil liberties impacts of the authentication-oriented proposals, if appropriately restricted to critical infrastructure, are lighter. Second, the attribution-oriented proposals address both the creation and deployment of new and unproven technologies, while the authentication-oriented proposals focus mostly on deployment alone, because existing authentication technologies are largely proven.

This suggests that given limited resources, policymakers should focus heavily on authentication-oriented policies as the more effective option for addressing the cyber security identity information deficit. These policies rely on established successful technologies rather than on unproven changes to the fabric of the network, and they carry fewer ancillary concerns for other national values such as civil liberties and in-

novation. This is so, in large part, because they can target where needed rather than requiring broad-based deployment across communications networks, and therefore the civil liberties penalties fall largely on the limited subset of users who access critical systems rather than the full spectrum of Internet users. Moreover, authentication improvements can also help address attribution concerns as they relate to critical systems – as part of the AAA model of identity and security, authentication can provide the basis for better auditing, which in turn can drive better attribution. By ensuring the deployment of state-of-the-art authentication technologies to critical systems, policymakers may also be able to eliminate a substantial portion of the attribution problem.

Separately, there is a follow-on question as to the right mix of incentives for deploying authentication technologies. Striking the right balance between financial incentives, regulatory commands, and collaborative government-industry standards-setting and research should be the key concern of policymakers. Given the potential economic consequences of the top-down regulatory approach that can backfire, legislators should promote incentives and collaboration as an alternative to regulation where possible.

CONCLUSION

Addressing the identity problems associated with cyber security requires policymakers to distinguish among the various functions of identity technologies, including authentication and attribution. Many proposed solutions aimed at improving online identity for cyber security purposes would impinge on other values. As a result, any attempt to intervene in online

identity technologies will demand a careful balancing of costs and benefits, with serious consideration given to that intervention's impacts upon civil liberties, economic freedom, technological innovation, and global discourse. After considering these issues in this more global context, policymakers will find that deploying better authentication technologies to critical infrastructure is the best first step in cyber security identity policy.

ENDNOTES - CHAPTER 6

1. This is not only a civil libertarian perspective. The need to balance competing values has been recognized in the Defense community as well. See *Report of the Defense Science Board Task Force on Defense Biometrics*, Washington, DC: Office of the Undersecretary of Defense for Acquisitions, Technology, and Logistics, March 2007, pp. 70-72.

2. Stephen T. Kent and Lynette I. Millett, eds., *Who Goes There?: Authentication Through the Lens of Privacy*, Washington, DC: National Academies Press, 2003, p. 19. The White House's *National Strategy for Trusted Identities in Cyberspace* (NSTIC) defines authentication as "verifying the identity of a user, process, or device." *National Strategy for Trusted Identities in Cyberspace*, Washington, DC: White House Office of the Cybersecurity Coordinator, April 2011, available from www.whitehouse.gov/sites/default/files/rss_viewer/NSTICstrategy_041511.pdf (hereinafter NSTIC), p. 8. See also Committee on National Security Systems, CNSS Instruction No. 4009, *National Information Assurance (IA) Glossary*, 2010, available from www.cnss.gov/Assets/pdf/cnssi_4009.pdf, p. 4 (authentication is "the process of verifying the identity or other attributes claimed by or assumed of an entity [user, process, or device], or to verify the source and integrity of data"). For an excellent introduction to authentication, see generally, *Who Goes There?*

3. "Identity" as used in discussions of digital authentication may be different from what we often assume the word means in an offline context. Online identity need not have any connection with real-world identity. See Posting of Kim Cameron to Kim

Cameron's Identity Weblog, July 18, 2007, available from www.identityblog.com/?p=838 ("digital identity can often just convey that you are a member of some group, or possess some characteristic [for example, your profession, employer, citizenship, role or age]. Similarly, it can indicate that you are the same person who visited a site previously – without conveying any personally identifying information").

4. *Who Goes There?* p. 36.

5. Insecure practices induced by having an unmanageable multiplicity of identity credentials include reusing identities and passwords for both low-security and high-security functions and storing one's hard-to-remember identity credentials in weakly-protected files. Researchers have "observe[d] numerous ways in which the technical failures of lower-security sites can compromise higher-security sites due to the well-established tendency of users to re-use passwords." Joseph Bonneau and Soren Preibush, "The Password Thicket: Technical and Market Failures in Human Authentication on the Web," paper presented at the Ninth Workshop on the Economics of Information Security (WEIS), Boston, MA, June 7, 2010, p. 1. The recent compromise of multiple systems at one consulting firm that provided computer security services exploited a range of such insecure practices. See Peter Bright, "Anonymous Speaks: The Inside Story of the HBGary Hack," *Ars Technica*, February 15, 2011, arstechnica.com/tech-policy/news/2011/02/anonymous-speaks-the-inside-story-of-the-hbgary-hack.ars. However, multiuse identities pose their own privacy and security issues, and, unless carefully implemented, can create more problems than they cure. For more detail, see Center for Democracy & Technology (CDT), *Issues for Responsible User-Centric Identity*, 2009, available from www.cdt.org/files/pdfs/Issues_for_Responsible_UCI.pdf. Among other concerns, when an individual uses a single identity for different purposes, the compromise of that identity may have far-reaching consequences. *Ibid.*

6. See, e.g., Baris Coskun and Cormac Herley, "Can 'Something You Know' Be Saved?" ISC'08: Proceedings of the 11th International Conference on Information Security, Heidelberg, Germany: Springer-Verlag Berlin, 2008, p. 421 (describing the divide between the three categories); John Brainard *et al.*, "Fourth Factor Authentication: Somebody You Know," ACM Computer and

Communications Security Conference, New York. ACM, 2006, p. 168 (discussing the use of a nontraditional fourth category).

7. For example, Craig Mundie, Chief Research and Strategy Officer at Microsoft, has suggested requiring users to present “Internet drivers’ licenses” when accessing the Internet. Steven Yates, “A ‘Driver’s License’ for Internet Users?” *The New American*, February 15, 2010, available from www.thenewamerican.com/index.php/tech-mainmenu-30/computers/2945-af-drivers-license-for-internet-users.

8. For the earliest description of levels of assurance for government systems, see Office of Management and Budget (OMB), Memorandum M-04-04, E-Authentication Guidance for Federal Agencies, Attachment A, 2003, pp. 3-4. “The OMB/NIST 4-level LoA model has been accepted by e-government, e-commerce and research initiatives in several countries.” Ning Zhang, *E-infrastructure Security: Levels of Assurance*, London, UK: Joint Information Systems Committee (JISC), 2007, p. 10.

9. *Electronic Authentication Guide: Recommendations of the National Institute of Standards and Technology*, Gaithersburg, MD: National Institute of Standards and Technology, SP 800-63, 2006.

10. The Liberty Alliance released its Identity Assurance Framework in 2008. Press Release, Liberty Alliance, “Liberty Alliance Releases Identity Assurance Framework,” June 23, 2008, available from www.projectliberty.org/news_events/press_releases/liberty_alliance_releases_identity_assurance_framework/?f=news_events/press_releases/liberty_alliance_releases_identity_assurance_framework. The Liberty Alliance has been absorbed into the Kantara Initiative, which in April 2010 issued an Identity Assurance Framework (IAF) that defers to and adopts the four levels provided by NIST SP 800-63. Kantara Initiative, “Identity Assurance Framework: Assurance Levels,” 2010, available from kantarainitiative.org/confluence/download/attachments/41649275/Kantara+IAF-1200-Levels+of+Assurance.pdf.

11. As this suggests, different commercial entities emphasize different aspects of identity. Practitioners of targeted advertising are interested in attribution, while commercial entities engaging in monetary transactions are most concerned with authentication.

A similar split may be found in the cyber security field. Information security officers spend more time implementing authentication, while law enforcement investigators and intelligence collectors and analysts are focused on attribution.

12. See the Kantara Initiative.

13. See Dave Morin, Facebook Developer Blog, May 9, 2008, available from developers.facebook.com/blog/post/108.

14. In one recent case, an online gaming service with 12 million subscribers attempted to make players use real names when posting on message boards, only to back down in the face of overwhelming customer criticism. See M. G. Babbage, The Economist Science and Technology Blog, July 13, 2010, available from www.economist.com/blogs/babbage/2010/07/online_gaming.

15. There is a relatively new computer security sub-discipline that explicitly addresses the relationship between usability and security. See National Research Council Steering Committee on the Usability, Security, and Privacy of Computer Systems, *Toward Better Usability, Security, and Privacy of Information Technology: Report of a Workshop*, Washington, DC: National Academies Press, 2010.

16. See Jeffrey Hunker, Bob Hutchinson, and Jonathan Margulies, *Roles and Challenges for Sufficient Cyber-Attack Attribution*, Hanover, NH: Dartmouth College, Institute for Information Infrastructure Protection, 2008, available from www.thei3p.org/docs/publications/whitepaper-attribution.pdf.

17. Former Director of National Intelligence Mike McConnell has suggested that “deterrence [is] based on a few key elements,” with the first being attribution. Mike McConnell, “Mike McConnell on How to Win the Cyber-war We’re Losing,” *The Washington Post*, February 28, 2010. See also William J. Lynn III, “Defending a New Domain: The Pentagon’s Cyberstrategy,” *Foreign Affairs*, Vol. 89, No. 5, September-October 2010, p. 97.

18. McConnell suggests “reengineer[ing] the Internet to make attribution, geolocation, intelligence analysis, and impact assessment . . . more manageable.” See McConnell.

19. David D. Clarke and Susan Landau, “Untangling Attribution,” *Proceedings of a Workshop on Deterring Cyber Attacks*, Washington, DC: National Academies Press, 2010, pp. 25, 31-32 (“Redesigning the Internet so that all actions can be robustly attributed to a person would not help to deter the sophisticated attacks we are seeing today, such as . . . multi-stage attacks. . .”).

20. The U.S. Government has supported anonymity in the service of various national interests. The U.S. Navy helped originate the Tor anonymous routing system to protect communications by military personnel, and domestic law enforcement agencies use it to shield their investigations. The State Department has supported the development and dissemination of anonymization and confidentiality systems for use by human rights activists.

21. International Telecommunications Union (ITU) Study Group 17 on telecommunications security has a subgroup looking at securing ubiquitous telecommunications services such as the Internet. Documents authored by one Chinese member were leaked from this Q6/17 subgroup in September 2008. They refer to use cases for tracing back traffic that include “political opponent[s] to a government publish[ing] articles putting the government in an unfavorable light.” Declan McCullagh, “U.N. Agency Eyes Curbs on Internet Anonymity,” CNet News, September 12, 2008, available from news.cnet.com/8301-13578_3-10040152-38.html. For further discussion of such traceback proposals, see Section IV.

22. See Federal Trade Commission, *Protecting Consumer Privacy in an Era of Rapid Change*, 2010, pp. 63-69 (recognizing potential value in a “Do Not Track” feature for web browsers and sites that would prevent online tracking).

23. IP addresses are assigned by the Internet Assigned Numbers Authority. They are given in blocks to governments, corporations, and regional Internet registries. Those parties rely on their own rules to assign or lease IP addresses to assorted third parties.

24. As noted in Section II, authenticators can include something you know, something you have, or something you are. See note 6 and accompanying text.

25. There are other authentication paradigms, but all rely on secure connections and the exchange of authenticators. For example, web-of-trust authentication requires a trusted third party to vouch for the user. However, this requires the trusted third party to present a key or token establishing his or her identity, which again requires an exchange of authenticators.

26. In a 2010 McAfee survey of executives in seven “critical infrastructure” sectors worldwide, 57 percent reported requiring only a username and password from users logging onto their systems. Stewart Baker, Shaun Waterman, and George Ivanov, *In the Crossfire: Critical Infrastructure in the Age of Cyber War*, McAfee, Inc.: Santa Clara, CA, 2010, p. 34, available from www.mcafee.com.

27. See, e.g., James A. Lewis, *Authentication 2.0 – New Opportunities for Online Identification*, Washington, DC: Center for Strategic and International Studies, 2008, p. 1 (noting that “we have very strong credentials that are not widely trusted and therefore not widely used. The problem—and the solution—to authentication do[es] not lie with technology.”).

28. See, e.g., OMB Memorandum 04-04, pp. vi-viii (linking each of the four LOAs to a set of technical characteristics of authentication systems that would satisfy those LOAs).

29. According to one 2006 survey of American business practices by the Air Force Research Laboratory, institutions often take action to improve cyber security only when confronted with a particular breach, or when regulatory compliance requires it, rather than engaging in comprehensive cost-benefit analysis. Research Triangle Institute, *Economic Analysis of Cybersecurity*, Rome, NY: Air Force Research Laboratory, 2006, pp. 13, 64-73.

30. This contention is much debated. Compare Bruce Kobayashi, “Private versus Social Incentives in Cybersecurity: Law and Economics,” *The Law and Economics of Cybersecurity*, New York: Cambridge University Press, 2006, pp. 13-28 (arguing that cyber security underspending should be expected, because cyber

security is a public good and because the substantial social harms caused by cyber security breaches are difficult to quantify) with Benjamin Powell, "Is Cybersecurity a Public Good? Evidence From the Financial Services Industry," *Journal of Law, Economics, and Policy*, Vol. 1, Winter 2005 (arguing that there is little empirical evidence that the financial sector underinvests in cyber security).

31. See Bonneau and Preibush.

32. This is, in many ways, the vision of the National Strategy for Trusted Identities in Cyberspace. See NSTIC. See also CDT report on Responsible User-Centric Identity (discussing proper implementation of multiuse identities).

33. See generally NRC report on Better Usability, Security, and Privacy (discussing usability as a security consideration).

34. Multistep and multistage attacks are discussed in greater detail in Clarke and Landau, "Untangling Attribution." In terms of IP address spoofing, the capability to send packets with spoofed addresses remains widespread years after responses to the problem were promulgated. The MIT Spoofer project collects data on the prevalence and efficacy of current best-practice source address validation techniques. The project found in its most recent report that, of clients able to test their provider's source-address filtering rules, 31 percent were able to successfully spoof an arbitrary, routable source address, while 77 percent of clients otherwise unable to spoof could forge an address within their own /24 subnetwork. Robert Beverly *et al.*, "Understanding the Efficacy of Deployed Internet Source Address Validation Filtering," paper presented at the ACM SIGCOMM/USENIX Internet Measurement Conference, Chicago, IL, November 4-6, 2009, p. 1.

35. This is less true when the endpoint system uses authentication. For this kind of last-mile attribution, authentication and auditing can be very helpful. See the latter proposals in Section IV.B for more detail.

36. Aaron Burstein, "An Uneasy Relationship: Cyber Security Information Sharing, Communications Privacy, and the Boundaries of the Firm," paper presented at the Sixth Workshop on the Economics of Information Security (WEIS), Pittsburgh, PA, June 7-8, 2007, p. 2.

37. See note 30 and accompanying text.

38. The relevant exceptions within the Wiretap Act and the Stored Communications Act allow sharing of information when it is a “necessary incident to the rendition of . . . service” or required for the “protection of the rights or property of the provider of that service.” See 18 U.S.C. §§ 2511(2)(a)(i) and 2702. Arguably, this does not allow one service provider to share information with another provider when the sharing, however useful to the recipient, is not necessary to the disclosing entity.

39. Convention on Cybercrime, November 23, 2001, CETS 185 (Council of Europe), available from conventions.coe.int/Treaty/en/Treaties/Html/185.htm. The United States is the only non-European nation to have ratified the treaty; Canada, Japan, and South Africa have signed it without ratification.

40. Proposals from both individual nations and UN work-groups have not gained traction. See John Markoff and Andrew E. Kramer, “U.S. and Russia Differ on a Treaty for Cyberspace,” *The New York Times*, June 27, 2009, p. A1; Stein Schjolberg, “A Cyberspace Treaty—A United Nations Convention or Protocol on Cybersecurity and Cybercrime, distributed to the United Nations Office on Drugs and Crime,” United Nations paper A/Conf.213/IE/7, March 23, 2010.

41. See, e.g., Authentication, Authorization and Accounting (AAA), Description of Working Group, available from datatracker.ietf.org/wg/aaa/charter/.

42. Note that there are cyber security experts on all sides of this debate—some argue attribution is a more pressing identity concern than authentication, while others have focused on authentication. For others, the most serious problem is neither authentication nor attribution, but vulnerable software. Compare McConnell, above, with CSIS Commission on Cybersecurity for the 44th Presidency, *Securing Cyberspace in the 44th Presidency*, Washington, DC, Center for Strategic and International Studies, 2008, pp. 54-55, 61-67 (emphasizing securely authenticated control systems as a key cyber security priority) and with Steven M. Bellovin, SMBlog, July 11, 2010, available from www.cs.columbia.edu.

edu/~smb/blog/2010-07/2010-07-11.html. (“The fundamental premise of [the draft NSTIC] is that our serious Internet security problems are due to lack of sufficient authentication. That is demonstrably false. The biggest problem was and is buggy code. All the authentication in the world won’t stop a bad guy who goes around the authentication system. . . .”) See also “Planning for the Future of Cyber Attack,” Testimony Before the House Committee on Science and Technology, Subcommittee On Technology and Innovation, 111th Cong., 2nd sess., July 15, 2010, statement of Robert K. Knake, International Affairs Fellow in Residence, The Council on Foreign Relations (“the problem of attribution has been over-stated for the high end threats that represent a challenge to our national security”).

43. See NSTIC, pp. 24-27 (explaining the policy role of the Identity Ecosystem Framework).

44. See CSIS, *Securing Cyberspace*, pp. 61-67.

45. While no bill specifically mentioned authentication, cyber security regulatory provisions allowing the Department of Homeland Security to promulgate mandatory “security measures” were present in bills in both the Senate and House last year. See Protecting Cyberspace as a National Asset Act, S. 3480, 111th Cong. § 248(b) (2010); Homeland Security Cyber and Physical Infrastructure Protection Act, H.R. 6423, 111th Cong. § 224(c) (2010). The leading Senate bill this year is the Cyber Security and Internet Freedom Act, S. 413, which contains identical language to S. 3480 regarding acceptable security measures. At least one authentication product manufacturer called last year for authentication-related regulation to top the list of mandates. See Philip Lieberman, “Applauding the Lieberman-Collins Cyber Security Bill S. 3480,” *Identity Week*, June 30, 2010, available from www.identityweek.com/applauding-the-lieberman-collins-cybersecurity-bill-s-3480/.

46. See S. 3480 at § 241(4) (defining covered critical infrastructure to include anything “that is a component of the national information infrastructure”).

47. See *McIntyre v. Ohio Election Commission*, 514 U.S. 334, 357 (1995) (calling anonymous speech part of “an honorable tradition of advocacy and dissent” and “a shield from the tyranny of the majority”).

48. Data breach notification laws passed in many states appear to have had a “limited impact . . . in pressuring businesses to make fundamental changes in their information security practices.” Jane K. Winn, “Security Breach Notification Six Years Later: Are ‘Better’ Security Breach Notification Laws Possible?” *Berkeley Technology Law Journal*, Vol. 24, No. 3, 2009, p. 1161. See Sasha Romanosky and Alessandro Acquisti, “Security Breach Notification Six Years Later: Privacy Costs and Personal Data Protection: Economic and Legal Perspectives,” *Berkeley Technology Law Journal*, Vol. 24, No. 3, 2009, pp. 1094-95. Meanwhile, tort liability for vendors of insecure software has been widely proposed but not implemented. See Michael D. Scott, “Tort Liability for Vendors of Insecure Software: Has the Time Finally Come?” *Maryland Law Review*, Vol. 67, No. 2, 2008, pp. 441-42 (briefly describing the history of proposals for a negligence standard for software vendors). Vendors’ liability to third parties for breaches of systems running those vendors’ software, however, has not yet been the subject of much academic attention. *Id.* at n.7.

49. See the sources in the previous note. Attribution difficulties also play a part in making the assignment of responsibility in these cases so complex.

50. See NSTIC.

51. See NSTIC, p. 5. (Suggesting users should be able to “choose to obtain [their] credentials from a range of different identity providers, both private and public”).

52. See Comments of AT&T, Inc., “In the Matter of Cybersecurity, Innovation, and the Internet Economy Before the Department of Commerce,” NTIA, Docket No. 100721305-0305-01, Sep. 20, 2010, pp. 18-20, available from www.nist.gov/itl/upload/AT-T_Cybersecurity-NOI-Comments_9-20-10.pdf.

53. See Convention on Cybercrime, art. 29-35.

54. See Council of Europe Project on Cybercrime, Messages from the Octopus Conference, March 20, 2010, pp. 1-2, available from www.coe.int/t/dghl/cooperation/economiccrime/cybercrime/cy-activity-Interface-2010/2079_IF10_messages_1p%20key%20

prov%20_26%20mar%2010.pdf (discussing the consensus of participants at the most recent COE conference on combating cybercrime, including statements that “[e]stablishing the Budapest Convention as the global standard goes hand in hand with strengthening the Cybercrime Convention Committee (T-CY) as a forum for information sharing” and that “[a]dditional international standards on law enforcement access to data stored in the ‘clouds’ may need to be considered”).

55. “[E]xecutives from many nations, including many U.S. allies, rank the United States as the country ‘of greatest concern’ in the context of foreign cyberattacks, just ahead of China.” McAfee, *In the Crossfire*, p. 25. It has been reported that the U.S. Government participated in the development of the Stuxnet worm as an alternative to assisting in a physical attack on Iran’s nuclear program. See William J. Broad, John Markoff, and David E. Sanger, “Israeli Test on Worm Called Crucial In Iran Nuclear Delay,” *The New York Times*, January 16, 2011, p. A1.

56. Most approaches fall into three categories: out-of-band communication between the router and recipient, logging at the router, or in-band communication between the router and recipient via packet modification. See, respectively, Steve Bellovin *et al.*, *ICMP Traceback Messages*, IETF Internet Draft, February 2003, available from tools.ietf.org/html/draft-ietf-itrace-04; Alex Snoeren *et al.*, “Single-Packet IP Traceback,” *IEEE/ACM Transactions on Networking*, Vol. 10, 2002, p. 721; Stefan Savage *et al.*, “Practical Network Support for IP Traceback,” paper presented at ACM SIGCOMM, Stockholm, Sweden, August 28-September 1, 2000.

57. According to one of the few public ITU memos on the subject, the Q 6/17 group referenced *supra*, note 21, has made IP traceback a “main study item,” and a group of editors has been assigned for the last 2 years to work on traceback proposals as a component of future networking equipment standards. See Memorandum from A. M. Rutkowski, Verisign, May 31, 2008, pp. 1-2, available from www.itu.int/osg/csd/cybersecurity/WSIS/3rd_meeting_docs/Rutkowski_IPtraceback_callerID_rev0.pdf.

58. See Anne Alexander, “Internet Role in Egypt’s Protests,” BBC News, February 9, 2011, available from www.bbc.co.uk/news/world-middle-east-12400319.

59. See Nicole Gaouette and Brendan Greeley, "U.S. Funds Help Democracy Activists Evade Internet Crackdowns," *Bloomberg News*, April 20, 2011, available from preview.bloomberg.com/news/2011-04-20/u-s-funds-help-democracy-activists-evade-internet-crackdowns.html.

60. The then-director of the Telecommunication Standards Bureau of the ITU proposed in 2004 that some portion of the IPv6 address space be allocated to nations, which would then be able to keep more accurate records of the ownership of IP addresses within their IP address blocks. Memorandum of Houlin Zhao, Director of TSB/ITU, to the ITU Council Working Group on WSIS, November 30, 2004, pp. 8-9, available from www.itu.int/ITU-T/tsb-director/itut-wsis/files/zhao-netgov02.doc.

61. See David G. Andersen *et al.*, "Accountable Internet Protocol," paper presented at ACM SIGCOMM 2008, Seattle, WA, August 17-22, 2008; Xin Liu *et al.*, "Efficient and Secure Source Authentication with Packet Passports," paper presented at USENIX Steps to Reducing Unwanted Traffic on the Internet, San Jose, CA, July 7, 2006.

62. See Mikhail Afanasyev *et al.*, "Network Support for Privacy-Preserving Forensic Attribution," Communications of the ACM, draft available from www.thei3p.org/docs/events/WESIIIdentity.pdf.

63. See McConnell.

64. They note that attribution of multistage attacks, the most serious challenge investigators face, is only marginally addressed by personal identification. Since multistage attacks make use of intermediaries, little additional information would reach the recipient. See Clarke and Landau, "Untangling Attribution," pp. 39-40. They also note there are technical means of subverting any attribution system for sufficiently motivated malicious actors, and therefore, sophisticated actors will continue to falsify their network identity. See Bruce Schneier, "Schneier-Ranum Face-Off: Should We Ban Anonymity on the Internet?" *Information Security*, February 2010. Finally, because sender identification cannot fully address the indirection or falsification problems, they indicate

that any evidence collected by investigators will never be definitive enough or of high enough forensic quality to serve the purposes that make attribution important: criminal investigation and the allocation of responsibility in international cyber attacks. See David D. Clarke and Susan Landau, "The Problem Isn't Attribution; It's Multi-Stage Attacks," paper presented at the Third International Workshop on Re-architecting the Internet (ReArch 2010), Philadelphia, PA, November 2010, pp. 3-4.

CHAPTER 7

EXPLORING THE UTILITY OF OPEN SOURCE DATA TO PREDICT MALICIOUS SOFTWARE CREATION

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A version of this chapter was presented at the annual meeting of the American Society of Criminology in 2009 in Philadelphia, PA, and at the Department of Defense Cybercrime Conference in 2010 in St. Louis, MO. The authors thank Joseph K. Young of Southern Illinois University, Carbondale, for his helpful suggestions about an earlier draft of this chapter.

INTRODUCTION

The information security community has developed a variety of tools to identify and defend against malicious software, though few in the social sciences have explored the environmental and social factors that may affect the creation and distribution of malware. This is due in part to the dearth of available data on the country of origin of malicious software developers and the volume of tools created by hackers across the world. Open source malware repositories exist in online environments, though it is not clear how valid or reliable this information may be to understand the scope of malware. This chapter explored the value of open reporting for malware creation and distribution, and considered how this information may combine with other measures to explore the country-level eco-

nomic, technological, and social forces that affect the likelihood of malware creation. The findings will improve our understanding of the value of open source data and the prospective influences of macro-level computer crime and hacking in a global context.

Although studies of cybercrime have grown exponentially over the last 2 decades, there are multiple issues regarding the validity and generalizability of cybercrime data.¹ In general, official data on most forms of cybercrime are non-existent, inadequate, or inaccessible to the public.² Though various entities in the private sector collect information on certain cybercrimes, malware trends, and specific attacks, they may be unwilling to share that information with researchers because of proprietary methods or information that may be lost.³ Therefore, most social science scholars interested in the phenomenon of cybercrime collect primary data, often from college students, to understand the scope and predictors of both participation in cybercrime and experiences with victimization. These studies provide useful information on various forms of cybercrime and cyber deviance, such as digital piracy,⁴ online harassment,⁵ and minor forms of computer hacking.⁶ These populations do not, however, appear to engage in the creation of malicious software or more serious forms of computer hacking, which limits our understanding of these phenomena.⁷

For those interested in studying cybercrime at the macro level, data collection and aggregation challenges are even more complex. Cross-national comparisons of crime have been problematic for the study of traditional crimes, since official crime statistics are not available or reliable for many non-Western nations.⁸ In addition, reporting crime to law enforcement agencies is not consistent across the world, creating pockets

of underreporting. Finally, behaviors are defined and criminalized differently across countries and regions. For example, N. L. Piquero and A. R. Piquero explain that the East and West view intellectual property differently.⁹ Developing nations that have desires for continued economic and technological growth may have no interest in passing and/or enforcing legislation protecting intellectual property, as this would otherwise hinder growth and development. As a consequence, cross-national research often examines more traditional and consistently operationalized offenses such as homicide, using data collected by international nongovernmental agencies.¹⁰

One way that researchers may move beyond the data aggregation issues affecting cybercrime is through the use of data developed in online environments such as web forums, bulletin board systems, and archival websites.¹¹ The emergence of the Internet enables significant social interactions between individuals across the globe, whether through real-time communications via email, or instant messaging, or asynchronous methods like blogs and texts.¹² As a consequence, researchers can mine these data sources for information to understand cybercrime better, much the same way as traditional ethnographic research on criminal behavior in the real world.

In particular, there are websites that act as online repositories that maintain information on the discovery and description of malicious software and attacks against various resources.¹³ Individuals in the hacker community often discuss the tools and resources they find with others in forums and chat rooms in order to gain social status or respect from their peers.¹⁴ Sharing resources may also help elevate an individual's reputation in the digital underground by demonstrating

their skill and ability.¹⁵ Furthermore, the computer security community maintains open source repositories of vulnerabilities and exploits—identified in various outlets—to improve awareness of security trends, thereby increasing overall levels of security.¹⁶

As a consequence, examining these sites can provide practical secondary data sets for social science researchers to understand the potential distribution of malware creators across the globe, the complexity or functionality of these tools, and the influence of various social factors on cybercrime at the macro-level. Data from these repositories can help fill the void left by the lack of reliable and accessible data by the government and private sectors. In addition, these repositories neither rely on governments to report data nor on individuals within a country to report the offensiveness or victimization that has occurred in that country. Instead, interested parties from other countries who have made discoveries can provide information on that software, alleviating many of the problems described and identified in Piquero and Piquero's study of software piracy, regarding cultural definitions of intellectual property and their willingness to protect it.¹⁷ Given the increasing availability and proliferation of open source repositories for information about cybercrimes and attacks in online environments, this study utilized a sample of data developed from one such repository to examine the macro-level predictors of malicious software creation.

LITERATURE REVIEW

The Problem of Malware.

Malicious software systems, or malware, include computer viruses, worms, and Trojan horse programs that can alter functions within computer programs and files, thus enabling attacks against a massive number of targets. Viruses can conceal their presence on computer systems and networks, and can spread via email attachments, downloadable files, instant messaging, and other methods.¹⁸ Trojan horse programs also often arrive via email as a downloadable file or attachment that people would want to open, such as photos, videos, or documents with misleading titles such as “XXX Porn” or “Receipt of Purchase.” When the file is opened, it executes some form of malicious code.¹⁹ In addition, some malware is activated by visiting websites, which exploit flaws in web browsers.²⁰ Though worms do not involve as much user interaction as other malware because of their ability to use system memory and to self-replicate, humans can facilitate their spread by simply opening emails that have the worm code embedded in the file.²¹

The losses associated with malicious software infections and theft are massive, due in part to the costs to remove these programs from a network, declines in productivity among employees and computer systems, and customer apprehension about compromised web pages or online resources.²² For example, U.S. companies who participated in a recent Computer Security Institute study reported losing an average of \$40,000 per respondent due to viruses and \$400,000 due to another form of malware called botnet infection.²³ Furthermore, the risk of malicious software is

difficult to mitigate, as almost 25 percent of personal computers around the world use a variety of security solutions that have malware loaded into their memory, compared with 33.28 percent of unprotected systems.²⁴ Thus, malware infection poses a significant threat to Internet users around the globe.

Despite the significant role and utility of malicious software in cybercrime, there is generally little research examining the creators or developers of malware. Individual-level studies suggest that the creators of malware tend to be lone hackers or individuals working in small groups to produce the tools that can be used for financial theft, fraud, or as an instrument to facilitate greater access to computer systems and networks for subsequent attacks.²⁵ Explorations of the hacker community indicate that hackers exist within a subculture that values profound and deep connections to technology.²⁶ This subculture is also a meritocracy where others are judged based on their capacity to utilize computers in unique and innovative ways.²⁷ Access to computer hardware, software, and Internet connectivity varies by place, though there is evidence to suggest hacker communities are present in areas across the emerging world, including North Korea, Central America, and Northern Africa.²⁸ Thus, one need simply obtain access to computer technology in order to participate within this community.

Hackers are also driven by a variety of motives, particularly status, ego, cause, entry into social groups, and, most notably, economic gain.²⁹ Hackers also have shifting ethical beliefs about hacking, which concern the consequences of their actions, as demonstrated by their willingness to share hacking, tools and sensitive or fraudulently obtained information in public outlets online.³⁰ Thus, developing and releasing a highly

functional program like a virus, worm, or Trojan horse is a sensible act for a hacker, because he or she may gain respect and status among others, and capitalize on these programs to generate a profit.

Despite the significant risks of hackers and malware to all individuals connected to the Internet, no agreement has been reached worldwide on the best strategies to curtail these problems. For example, the U.S. Computer Fraud and Abuse Act can be used to prosecute the distribution of malicious software through “any computer connected to the Internet, regardless of whether the computers involved are located in the same state.”³¹ Similar statutes, or models for statutes, such as the United Kingdom (UK) Computer Misuse Act and the Council of Europe Convention on Cybercrime, are in place in industrialized nations to prosecute malware writers and distributors.³² Emerging industrial nations, however, are less likely to have developed legal guidelines related to malware and other forms of cybercrime.³³ As a result, there are now legal safe havens where malware writers and hackers can operate with minimal risk of extradition and prosecution.³⁴ For instance, individuals sell services to host malicious software and pornographic materials in Malaysia and other parts of Southeast Asia, where there are fewer legal risks for the buyers, sellers, and operators.³⁵

THEORIZING THE STRUCTURAL CORRELATES OF MALWARE CREATION

Though scholars are starting to learn more about hackers and their subculture, little research exists on the macro-level factors that provide a supportive milieu for individuals to develop malicious software. This

is problematic, considering that evidence suggests a great deal of modern malware is created and used by computer hackers in foreign countries, particularly China, Russia, Brazil, and Eastern Europe.³⁶ Few have considered what technological, economic, or social conditions engender the development of malware in these nations, and little to no research considers what forces constrain malware creation. This is a particularly significant issue, given the changing landscape of technology and the economic and social conditions related to access to the Internet and computer resources. As a consequence, it is unclear what factors encourage or hinder malicious software production.

For example, the gross domestic product (GDP) of a nation may have a significant influence on the level of malware produced by a given nation. Specifically, as the economy of a nation improves, this will increase the proliferation of technological infrastructure and resources, which may increase the capacity for actors to become part of the larger international hacker community. Countries with poor economic conditions in comparison to other countries may have less access to high-speed Internet connectivity and powerful computer technology, diminishing the resources available to hackers.³⁷ A strong economy may also foster a competitive and stable educational system in which computer skills are taught, thus providing a larger labor force with more advanced skills. As long as there is economic growth and stability, individuals with computer skills and training should have access to legitimate jobs within the information technology service sector where many hackers find legitimate employment. Developing nations appear to have an interest in creating and using malicious software that can be applied in information-warfare campaigns against

rival nations.³⁸ Such attacks can be performed with minimal economic investment and low risk of attribution to the originating nation, thereby increasing their overall efficiency. Thus, it is hypothesized that, as GDPs increase, countries become more suitable environments for hackers and the creation of malicious software.

In addition, the number of Internet hosts available in a nation may play a critical role in enabling hackers to create and distribute malware. The global connectivity afforded by the Internet engenders hackers to identify and use resources created by different entities around the world.³⁹ At the same time, research has noted that substantial hacker communities in Russia, China, and Turkey often utilize web resources created and hosted within their nations as a means of limiting access to outsiders.⁴⁰ Thus, if a nation has a larger number of web-hosting resources available, there may be greater opportunities to develop, promote, and share malware and hacking information to their fellow countrymen. This suggests Internet hosting may have a positive impact on the creation of malware.

A country's political system may also influence the production of malware. In theory, one would speculate that democratic or representative government structures, which provide fewer restrictions on individual behavior, would be more likely to encourage innovation and creative efforts. As a consequence, hackers could work covertly to develop resources with less fear of brutal reprisals from the government.⁴¹ However, democratic countries are generally where intellectual property originates, and thus has some of the most stringently enforced intellectual property laws.⁴² In addition, totalitarian regimes have historically allowed hackers to attack victims in other nations and

have employed or exploited hackers as a means to attack competing democracies.⁴³ For example, there are a number of reports indicating that hackers with ties to the Chinese military or government have engaged in attacks against the United States and other nations in order to steal sensitive information.⁴⁴ Since the identification of individual hackers is difficult, countries can target their enemies through individual hackers without fear of political reprisal. Thus, it is hypothesized that malware will be more often created and utilized in countries with totalitarian regimes than in democratic nations with more political rights.

The ethnic and religious composition of a nation may also affect what countries are more likely to host the creation of malware, but it might affect it on a case-by-case basis. Specifically, a substantial mix of ethnic groups or religions within a nation may cause civil unrest and lead to attacks against different groups within that nation. A predominant ethnic identity within a nation may lead a minority group to utilize hacks and malware as a force multiplier against the government.⁴⁵ This is evident in Sri Lanka, where an offshoot of the group the Tamil Tigers uses hacking techniques as a means of disrupting government operations.⁴⁶ However, a homogeneous population might simply aim its attacks outwardly rather than inwardly. For example, Turkish hackers frequently attack targets outside of the borders of their Muslim-majority nation.⁴⁷ Thus, it is unclear what effect ethnic and religious compositions may have, if any, on malware production.

THE PRESENT STUDY

Despite the significant problems posed by malware, there is little research examining the economic, technological, and social factors that may affect its creation. In this chapter, we propose that online repositories containing data on malicious software can be valuable to study the macro-level correlates of malware creation. If fruitful, this would provide researchers with an additional avenue to study malware specifically and cybercrime generally. Some prospective hypotheses can derive by considering the extant literature on computer hackers and technology adoption. Specifically, environments will be more suitable for the creation of malicious software as GDP and Internet hosts increase in countries governed by regimes that limit political rights. It is unclear how ethnic and religious composition will relate to malware creation. Adopting a similar strategy used by K. Drakos and A. Gafos in their study of transnational terrorists attacks,⁴⁸ this study explored the global variation in the production of malicious software through a zero-inflated negative binomial regression (ZINB). In this way, this chapter contributes to the literature by developing an empirical profile of country-level variables that can predict malicious software production while illustrating the usefulness of open source repositories.

DEPENDENT VARIABLE

The data for the dependent variable used for this study (MALWARE) came from an open source malware repository where individuals could post information obtained on malicious software, either because

the individual created a program or identified it in the wild.⁴⁹ This open source repository provided self-reported information on malware around the globe. In order to report information to the website, an individual would send an email detailing the tool with as much information as possible to the site's director. This repository has been in existence for some time, as it maintains records on malware going back to 2001. Such information would suggest the repository had some recognition in the computer underground and was reputable. It is, however, apparent that self-reporting may undercount the actual number of malicious software produced and released by the hacker community.

Given the range of years available, the dependent variable for this analysis was the number of reported malicious software programs reported in a country in the years 2006, 2007, and 2008 (see Table 7-1 for descriptive statistics). It was necessary to combine multiple years as the number of countries reporting a positive count was extremely low each year: 18, 24, and 18, respectively. Combining these years, however, increased the number of countries with a positive count to 30. This ensured sufficient power for both processes in the ZINB model. Limiting the years included minimized errors due to lagged effects or changes in the predictor variables for these independent variables from 2008.

Many of the malware reports did not identify a country of origin for these tools (50 percent of all). As a result, a number of cases were excluded from the analysis, which may affect the undercounting of countries in this chapter. There is, however, significant difficulty in properly identifying the point of origin for a piece of malicious software.

Number of reported programs	Countries
0	Afghanistan, Albania, Algeria, Andorra, Angola, Antigua and Barbuda, Armenia, Australia, Austria, Azerbaijan, Bahamas, Bahrain, Bangladesh, Barbados, Belarus, Belize, Bhutan, Bolivia, Botswana, Brunei, Burkina Faso, Burma, Burundi, Cambodia, Cameroon, Canada, Chad, Costa Rica, Cote d'Ivoire, Croatia, Cyprus, Czech Republic, Djibouti, Dominica, Dominican Republic, Ecuador, El Salvador, Estonia, Ethiopia, Fiji, Finland, Gambia, Ghana, Greece, Grenada, Guinea, Guinea-Bissau, Guyana, Haiti, , Hungary, Iceland, Indonesia, Ireland, Israel, Japan, Jordan, Kazakhstan, Kenya, Kiribati, South Korea, Kyrgyzstan, Laos, Latvia, Lesotho, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Macedonia, Malaysia, Mali, Marshall Islands, Mauritania, Mauritius, Micronesia, Moldova, Mongolia, Mozambique, Namibia, Nauru, Nepal, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Paraguay, Philippines, Samoa, Senegal, Sierra Leone, Singapore, Slovakia, Slovenia, Solomon Islands, Somalia, South Africa, Sri Lanka, Sudan, Swaziland, Switzerland, Taiwan, Tajikistan, Thailand, Togo, Trinidad and Tobago, Turkmenistan, Tuvalu, Uganda, United Arab Emirates, United States, Uruguay, Uzbekistan, Vanuatu, Vietnam, Zimbabwe
1-10	Bosnia Herzegovina, India, Ukraine, United Kingdom, Venezuela, Saudi Arabia, Italy, Peru, Syria, Bulgaria, Chile, Mexico, Argentina, Colombia, Morocco, Spain, Egypt, Tunisia
11-20	Netherlands, Romania
21-50	Belgium, France, Georgia
51-115	Germany, Brazil, Russia, Turkey, Iran, Poland
116-360	China

Table 7-1. Counts of Malicious Software Programs Across Countries.

Specifically, a malware writer may state where he or she created their tool in the program notes, or post their tool directly into this repository providing the necessary information. Some programs may not con-

tain such information, however, and an individual may ascribe an origin point based on the language character set, such as Cyrillic, Chinese, or Western, used in the user interface of the tool kit. While these conditions may affect the validity of the dependent variable, it is still likely that the attributions are accurate and provide some insights into the location of malware creation.

INDEPENDENT VARIABLES

The data for the independent variables derived from the *CIA World FactBook* and from Freedom House, a nongovernmental agency that collects annual data on political freedom around the globe.⁵⁰ In order to model the number of reported malicious software programs, we included several co-variates in both the binary and count models. We examined measures on GDP and technological structure, political rights, and population diversity.

In the count model, the first group included measures of GDP and the number of Internet hosts within the country. We used the log of the GDP per capita (*Log GDP*) and the log of Internet hosts (*Log Hosts*), both from the *CIA World Factbook*.⁵¹ We logged the values for these two variables because both distributions were skewed. We also included other measures of technology infrastructure, including the number of cell phones, radio and television stations. However, because these variables all highly correlated with both *Log GDP* and *Log Hosts*, we could not include them in the same model.⁵² Furthermore, we attempted to include country population as a control variable, but not surprisingly, it was highly correlated with all the predictor variables and also could not be included in the regression model.

The second variable included in the models was the degree of political rights (*political rights*) as measured by Freedom House.⁵³ The variable ranged from 1 (the most free) to 7 (the least free). Freedom House's measure of political rights is based on a checklist of 10 political rights questions that fall into four subcategories: electoral process, political pluralism, participation, and functioning government. These scores are then used to create the political right subscale.

For measures of diversity, we included two variables: ethnic heterogeneity (*ethnicity*) and religious heterogeneity (*religion*). Both measures derived from the CIA *World Factbook* data, using P. M. Blau's heterogeneity index, calculated as $1 - \sum P_i^2$, where P_i is the proportion of each religious or ethnic group.⁵⁴ The squared proportions are summed and subtracted from 1, which gives an index from 0 (total homogeneity) to 1 (total heterogeneity). A higher Blau's index indicated more heterogeneity in the two measures.

Finally, we included a dummy variable for countries on the Asian continent, such as China and North Korea, as a control variable. This variable included Middle Eastern countries such as Iran and Afghanistan as well. Research indicates that Asian countries appear to be a prominent source of malware and hacker activity.⁵⁵ In addition, countries with non-Latin alphabets, like China or Iran, might have been more easily detected and have a higher likelihood of being reported in the malware dataset.

COUNT DATA ISSUES: THE ZERO-INFLATED NEGATIVE BINOMIAL MODEL

Our dependent variable (*MALWARE*) reported the count of malicious software detected within each country. Using an ordinary least squares regression

(OLS) was problematic because *MALWARE* was not normally distributed. It was right-tail skewed, as only a few countries reported hundreds of malicious software programs. The remaining countries reported far less than 100, most reporting 0. Thus, the modal count was 0, which resulted in an abundance of 0s in the variable's distribution. In fact, 80 percent of countries reported no malicious software during the study period. Furthermore, the data were reported counts, omitting some countries that undoubtedly produced malicious software, but were not detected by the reporting program. Because of these issues, using OLS regression was likely to result in biased standard errors and coefficients.

To remedy these problems, several limited dependent variable regression models for count data may be employed, including Poisson, zero-inflated Poisson, negative binomial, and zero-inflated negative binomial. A discourse on the differences among these models is beyond the scope of this chapter.⁵⁶ Using STATA 8.0, the calculations employed a zero-inflated negative binomial model for two reasons. First, the variance was greater than the mean, resulting in over-dispersion; thus, a Poisson model that assumes equal dispersion was eliminated. Second, the abundant zeros in the frequency distribution likely came from two different groups: the *Always-Zero group* (a country that never produced malicious software) and the *Not-Always-Zero group* (a country that likely produced malicious software).

For example, consider a country from the dataset likely in the *Not-Always-Zero group*. The United States, a technologically advanced country known to have a historically active hacker population,⁵⁷ reported zero malicious programs during the study period. The as-

sumption was that this zero count resulted from the reporting process failing to detect malware from the United States. The United States would therefore likely be in the *Not-Always-Zero group*. Since our data did not indicate which group a country belonged to, other than subjective estimation, membership in either of the two zero groups was therefore latent or unobserved. This last point was an important element in favor of a ZINB model, because Poisson or negative binomial models could inflate the probability of a country producing zero programs. The ZINB model predicted membership in either of the two latent groups.

To do this, the ZINB model included two processes in the estimation of the outcome count variable: a binary model and a count model. The binary (or inflated) model, typically logit, predicted the membership of a case in the *Always-Zero group* versus the *Not-Always-Zero group*. The first process accounted for membership in the two groups, while the second count model then predicted the number of counts among countries in the *Not-Always-Zero group*. Both models are reported in the results of a ZINB regression.

The decision to employ a ZINB should be based on the researchers' substantive understanding of how the data were generated, especially when the counts are subject to reporting bias.⁵⁸ However, a researcher should also consider the Vuong test.⁵⁹ The Vuong statistic can be used to test whether the ZINB model fits the data better than a negative binomial regression. If the Vuong statistic is significant ($V > 1.96$), a ZINB should be employed instead of a negative binomial regression.⁶⁰

The ZINB model then predicted the count of reported malware programs by country based on GDP, Internet hosts, political rights, ethnic heterogeneity,

and religious heterogeneity. For the *Always-Zero* inflation model, the study included two predictors: Internet hosts and political rights. Only 30 countries reported malware. Thus, the study minimized inflation in the model to keep it as parsimonious as possible. Given that authoritarian regimes and countries with more Internet hosts are likely producers of malware, these two predictors should confirm or refute current thinking on cross-national production of malware.

FINDINGS

The available data resulted in 147 countries in the sample, which are reported in Table 7-1. The modal count of reported software was zero. Thirty countries reported producing one or more malicious software programs in the sample years. China reported the highest number of software, 353 counts—which is in keeping with emergent research on Chinese hacker activity.⁶¹ It is important to remember that many of the countries in the zero category were actually producers of malware. Such countries likely produced malware in the sample, but they were not detected and reported to the website. Also, it is likely that these countries may have been reported to the website, but the country of origin was not discernible. The ZINB model attempts to replicate the differences in zero counts (i.e. true zeros [no malware] and non-zeros [failure to detect]).

The descriptive statistics for reports of malicious software and the predictor variables appear in Table 7-2. As mentioned previously, the variance of the dependent variable was greater than the mean ($s^2=1108.291$; $m=6.966$), indicating over-dispersion and ruling out a Poisson model. Because GDP and Hosts were logged, their mean levels are difficult to

interpret and not as useful, but the values are reported in Table 7-2. The average level of political rights was 3.262, about the middle of the Freedom House scale. The mean levels of religion and ethnic heterogeneity were 0.398 and 0.363, respectively.

Variable	Mean	s.d.	Min	Max
Malware	6.966	33.291	0.000	353
Log GDP	8.796	1.300	5.298	11.282
Log Hosts	10.095	4.261	0.000	19.571
Rights 3.262	2.185	1.000	7.000	
Religion	0.398	0.245	0.000	0.868
Ethnicity	0.363	0.254	0.000	0.950

Table 7-2. Descriptive Statistics (n=147).

Table 7-3 reports the results for the ZINB model. First, the zero-always inflation model reports the likelihood of a country never having reports of malicious software. The results of the Vuong test indicated that the ZINB model was an improvement over a negative binomial model ($V=2.32$; $p< 0.01$). More Internet hosts reduced the likelihood of being in the *Always-Zero group* ($b=-1.507$). Thus, more hosts increased the likelihood of being malware producers. Fewer political rights also reduced the likelihood of being in the *Always-Zero group* ($b=-2.135$), meaning that countries with fewer political rights were more likely to have been creators of malware.

Covariate	b	s.e.
Zero-always Inflation Model (Logit)		
Log Hosts	-1.507*	0.720
Political Rights	-2.135*	1.088
Constant	23.443*	10.943
Zero-inflated Negative Binomial Model		
Log GDP	0.054	0.255
Log Hosts	0.504***	0.500
Political Rights	0.297	0.134
Religion	-5.798**	1.786
Ethnicity	-0.658	1.559
Constant	-4.492	5.460
Log Likelihood	-169.844***	
Vuong test	.32*	
Maximum Likelihood R2	0.314	
Notes: * $p < 0.5$ ** $p < .01$ *** $p < .001$		

Table 7-3. Zero-inflated Negative Binomial Regression for Count of Malicious Software(n=147).

Separating the two kinds of zero counts into the *Always-Zero* and *Not-Always-Zero* groups allowed us to consider the zero-inflated negative binomial results as presented in Table 7-3. More Internet hosts (logged) increased the number of reported malware programs ($b=0.504$). Religious heterogeneity was negative, indicating that a more heterogeneous religious milieu re-

duced the number of reported malware programs ($b = -5.798$). Log GDP, political rights, and ethnicity were not significant.⁶²

A dummy variable was added to control for Asian countries to partially rule out the possibility that countries with a non-Latin alphabet would be more likely to be recognized and reported. Thus, higher counts for Asian countries might have resulted from ease of detection rather than an increased propensity for malware creation. In addition, it was possible that the associations between Internet hosts, political rights, religious heterogeneity, and malware creation were simply due to several Asian countries being high producers of malware. It was therefore important to examine whether these concepts relate to malware generally or whether they were simply descriptive of many Asian countries that happened to be high producers of malware.

The results of this model are reported in Table 7-4. In the *Always-Zero* inflation model, more Internet hosts and less political rights remained significant, both predicting less likelihood of being in the *Always-Zero* model as in the previous model. The dummy variable for Asia was also significant and positive ($b = 2.484$), indicating that Asian countries were more likely to be in the *Always-Zero* category than non-Asian countries, meaning that they were more likely to not produce it. The dummy Asian measure did not solely account for the relationship between Internet hosts, political rights, and malware, considering that these two measures remained significant in the model. However, it should also be noted that the coefficients decreased substantively between Tables 7-3 and 7-4. This illustrates that the Asian measure did partially mediate the effect of those two measures on malware creation.

Covariate	b	s.e.
Zero-always Inflation Model (Logit)		
Log Hosts	-0.634**	0.213
Political Rights	-0.861*	0.363
Asia	2.483*	1.001
Constant	10.067**	3.392
Zero-inflated Negative Binomial Model		
Log GDP	0.512	0.483
Log Hosts	0.302*	0.500
Political Rights	0.063	0.271
Religion	-3.818*	1.786
Ethnicity	-0.484	1.244
Asia	1.540	0.862
Constant	-5.591	5.719
Log Likelihood	-168.0059**	
Vuong test	1.93*	
Maximum Likelihood R2		
Notes: * $p < 0.5$ ** $p < .01$ *** $p < .001$		

Table 7-4. Zero-inflated Negative Binomial Regression for Count of Malicious Software Controlling for Asian Countries (n=147).

In the zero-inflated negative binomial component of the model, the results were similar to the results shown in Table 7-3. Again, only Internet hosts and religious heterogeneity were significant predictors. Thus, the Asia measure did not account for the prediction in reported malware in the count model, either.

In order to make the results more intuitive, predicted counts were calculated for malicious software and the probabilities for being in the *Always-Zero group* from the first regression model (reported in Table 7-3). The results for six countries are reported in Table 7-5. Afghanistan, the first country, had zero reported malware programs during the study period and zero predicted malware programs. The probability for being in the *Always-Zero group* was 0.999. Thus, Afghanistan was correctly classified based on the available data. Next, the United States and Jordan both had zero reported malware programs. The United States was predicted to have 15 reports of malware, while Jordan had only seven. Both countries had very low probabilities of being in the *Always-Zero group*, 0.000 and 0.096 respectively. Finally, three countries had positive observed reports of malware—Turkey (90), Egypt (10), and China (353). Two of the countries, Turkey and Egypt, had about the same number of reported as predicted counts of malware, 96 and 14, respectively. China, however, had far fewer predicted than expected counts (77 versus 353). All three of these countries had zero probability of being in the *Always-Zero group*, and because they were observed to have counts of malware, they were in the negative binomial part of the distribution. These results show how the ZINB regression attempts to model cases where the reported nature of the data produces inaccurate counts.

The probability of having a zero count is also shown in Figure 7-1. The figure shows the change in probabilities of a country having a zero count for each level of political freedom from the most free (1) to the least free (7). All of the other predictor variables are set to their mean values. When zeros from both

	Y	\hat{Y}	p	
Country	Count	Count	zero	Distribution
Afghanistan	0	0	.999	Always zero
United States	0	15	.000	Negative binomial
Jordan	0	7	.096	Negative binomial
Turkey	90	96	.000	Negative binomial
Egypt	10	14	.000	Negative binomial
China	353	77	.000	Negative binomial

Notes: \hat{Y} is the predicted count based on the negative binomial model. The column for ' p zero' is predicted probability that the country is in the *Always-Zero* distribution.

Table 7-5. Observed and Predicted Values for Counts and Probability of Always-Zero Group From Regression Model.

equations are 1.00, the probability of a zero count is 1.00. As countries become less free, the probability of a zero count drops to 0.600. Also, note that in the binary equation that as the level of political freedom approaches its highest value, the probability of a zero in the model drops to zero.

DISCUSSION AND CONCLUSIONS

The diverse and sophisticated threats posed by hackers and malicious software writers require significant investigation by both the technical and social sciences to understand the various forces that affect participation in these activities. It is, however, challenging to identify reliable data sources to examine trends and correlates of malware and hacking events from governmental sources. As a consequence, social

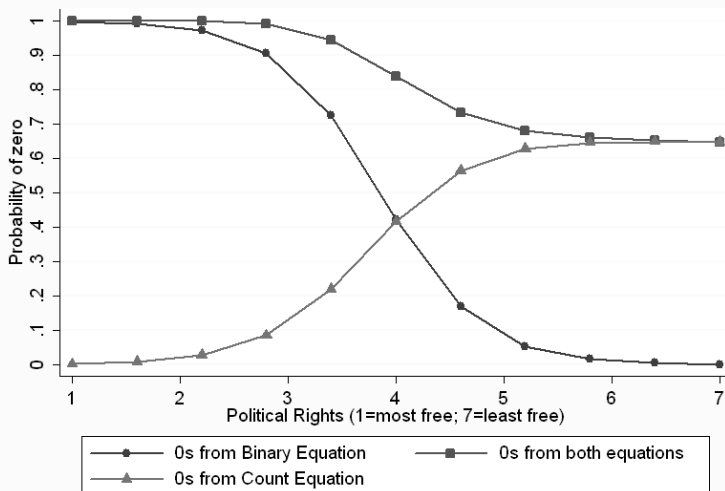


Figure 7-1. Probability of Country Having 0 Reports of Malicious Software by Political Rights.

science research may benefit from data mining online forums and websites to develop data sets.⁶³ Such efforts may prove beneficial, as online data enable individuals to provide direct information on various forms of cybercrime without stigma or fear that may otherwise result from contacting law enforcement agencies. This study attempted to demonstrate the value of such data through a country-level analysis of the economic, technological, and social forces that affect malware production based on reports to an international online malware repository.

The findings suggest malware production does not depend on a nation's economic conditions unless it affects the development of its technological infrastructure. Those nations with a larger number of Internet hosts were more likely to develop malware resources, because these nations have more opportunities

for their citizens to offend. Thus, greater information technology infrastructure may increase the number of people who can go online and increase the development of hacker communities and malware creation.

Considering that GDP did not relate to malware production when controlling for Internet connectivity, this implies that hackers can produce malware with efficiency and can perform this task regardless of legitimate employment opportunities provided by the markets.⁶⁴ Additionally, this finding gives some support to the value of malware as a force multiplier in attacks against various targets, as they do not require significant economic investment to be completed. As a result, there may be little policy value to consider how G20 nations are involved in cyber attacks, but rather, to explore the diverse nature of the hacker threat in a global context.⁶⁵ For example, understanding the relationships and intersections of hacker communities around the world through online environments may give some insight into the spread of techniques and utilities to develop malware.

This analysis also indicated that more repressive governments created environments in which malware production was more likely. This suggests there is a relationship between political oppression and the development of attack tools. It is unclear, however, if these tools were being created as a means to attack other nations to steal information, engage in espionage, or engage in internal attacks as a means of liberation. The negative effect of religious heterogeneity on malware production, however, suggests that malware was not designed as a means of affecting individuals' religious views within their own country.

The exploratory nature of this chapter provides multiple directions for future research. Specific-

ly, there is a strong need for greater qualitative and quantitative examinations of hacker communities around the world. Research on hacker subcultures in the United States,⁶⁶ China,⁶⁷ and Russia⁶⁸ suggest that there are norms, justifications, and beliefs that drive individual action. Examining the subcultural norms of hacker communities in established and emerging nations in Asia, Northern Africa, and South America can provide insights into the influence of the economic, political, and religious milieu of a nation on hacker activity.

The self-report nature of the data used to develop the dependent variable, malware creation, also suggests a need for further investigation using online data sources on the prevalence and characteristics of malicious software. Many cybercrime scholars have argued for greater official statistics on cybercrime offenses from law enforcement, government agencies, and the private sector.⁶⁹ The presence of such published statistics could provide greater insight into the problem of malware, although there is little likelihood that these entities would provide such information to the academic research community. Instead, utilizing data sources such as the information in this analysis provides a necessary and practical alternative to closed sources.

Though there are limitations with the data used in this chapter, as in all self-reporting studies, the work has demonstrated that reporting efforts can be successful in modelling computer crime. The results of this chapter suggest a more concentrated effort by government or academic institutions in collecting self-reported malware production is worth pursuing. Widely publicizing an Internet site where white-hat hackers, Internet security professionals, and laypersons could log detection of malware programs would

improve the reliability of the data. Furthermore, such a reporting effort could create a database in which highly visible cyber attacks reported in the media are collected and analyzed, similar to efforts by the University of Maryland's National Consortium for the Study of Terrorism and Responses to Terrorism (START) Center. Given the clandestine nature of hacking, the anonymity of reporters would need to be emphasized and assured to increase participation in reporting. Some kind of verification protocol, such as snippets of code or screenshots of user interface screens, should be implemented to ensure the accuracy of information provided.

Combining this chapter with technical analyses of malware would also allow for some examination of the technical sophistication of the tools created by hackers in each country. Such information could give additional nuance to this study and may demonstrate relationships between the macro-level variables included. For example, if there is a correlation between the production of software designed to steal financial information and the economic or political climate of a nation, this information may help to better understand the drivers for financially motivated cybercrime. Alternatively, examining the programming languages within which these programs are written could be used as a proxy for technical sophistication and skill. If any relationship can be identified between coding languages and technological, economic, or political drivers, such examination may help to better identify the forces that influence malware creation. In turn, this can help to improve understanding of malicious software production at the national level.

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