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JOHN PALFREY & URS GASSER[*]

A. Introduction

I. Roadmap of Paper

This paper takes up two main issues. First, we discuss the importance of interoperability in information and information systems, with a focus on trade in the global economy over time. Second, we argue that, despite the benefits to be gained from high levels of interoperability in information and information-related systems, there are barriers to adoption and new problems that must be tackled in our increasingly interoperable and global trade context.

We make these two core points in the context of a broader argument that we seek to advance: that higher levels of interoperability in the Information and Communications Technologies (ICT) field tends to be good from a trade perspective. This argument hinges on three primary observations. Higher levels of interoperability tend to foster innovation; to help economic players recover from the market turmoil (or any other economic challenges) by lowering costs and adding flexibility in terms of decision-making; and to help bring down barriers between market actors, across boundaries such as physical and political geography.[1] We advance this broader argument by developing a series of case studies in a range of areas. We have taken deep dives into cases as diverse as transportation, agriculture, currency, air traffic control, electronic health records, and cloud computing. Among these many examples, the case for higher levels of interoperability as favorable to trade is particularly strong, if not strongest of all, in the context of information and information systems.

The first of our two arguments, the importance of interoperability to trade in the information and information systems context, is a relatively straightforward case to make. With respect to the importance of interoperability in information systems, we discuss the high level of interoperability extant among e-mail systems. The ability to send emails from one system designed in China to another system designed in India and one designed in Switzerland enables communications to flow more freely and quickly than in the past. With respect to the importance of interoperability in information, we describe the Electronic Data Interchange (EDI) system that has become so pervasive in the global economy and the related role played today by implementation of the eXtensible Markup Language (XML). The introduction of information systems powered by these concepts into commerce has changed the way many businesses operate. These common examples demonstrate that the adoption of industry standards, social norms, and open technical aspects of the Internet drive information interoperability.

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[1] Urs Gasser and John Palfrey, Fostering innovation and trade in the global information society: The different facets and roles of interoperability, in Mira Burri and Thomas Cottier (eds.), *Trade Governance in the Digital* Age, Cambridge: Cambridge University Press, 2012,

The harder argument is the second topic we take up: we seek to understand and to address the problems that arise when we aspire to achieve higher levels of interoperability in information and information systems in the service of trade. The obstacles to optimal levels of interoperability include cost, collective action, and privacy concerns that arise as systems become more interoperable. These barriers to interoperability are particularly visible through the example of electronic health record systems. The drive to consolidate many forms of medical information into nation-wide, and potential international, systems sounds promising at a conceptual level. There is very little disagreement that interoperability in such systems is a worthy goal from a societal viewpoint, and as a matter of promoting trade at large. But so far, most governments that have tried to tackle this problem in a comprehensive way have so far failed, sometimes after spending billions of dollars and many years working toward these goals. Interoperability among health-related information and information systems requires governments and actors to first address these tricky issues that tend to arise in similar cases.

A final case that we take up, as part of our consideration of the puzzles to which interoperability gives rise, is the problem of interoperability over time in information and information systems. The manner in which information interoperability is becoming increasingly problematic can be easily seen through the example of media storage. In our increasingly digital age, we fear, with reason, that we will not be able to "replay" information stored in once prominent, now obsolete digital formats over time. Consider the utility today of an eight-track tape or a 3-1/2 inch floppy disk. For most of people, in the context of trade or otherwise, this information is not easily accessible, because we lack the proper equipment (ordinarily, computer hardware and software) to render (in order to view and then to make sense of) this information. To us, such disks in previous formats represent "data rot"—the problem of formats and devices becoming obsolete. This data rot will almost certainly afflict today's omnipresent formats like the PDF, DVDs, and thumb drives. The bar codes and QR codes used to connect mobile devices to information on the Internet in today's social web may prove even more transient. It may be that we wish for such information to be ephemeral in this sense; other information, we fear, we will want to be able to preserve and to access over time.

In this paper, we advocate for a system of ensuring backwards compatibility of information formats and modes of access and preservation that will enable continued, stable growth of international trade, common modes of production, increased cross-cultural understanding, and preservation of information needed for the continued understanding of cultural and economic heritage. Such a system will not be easily to establish, but much will turn on whether we will prove successful in this respect.

B. Interoperability in Information and Information Systems

1. Summary

In this section, we discuss the benefits of interoperability in information as such and in information systems related to trade. First, we define what we mean by information-related interoperability. To demonstrate the principles of information interoperability, we discuss the basic design principles behind e-mail. Shifting to the world of real goods, we then focus on how information interoperability has also greatly changed the face of commerce. In particular, we analyze information-related systems that rely upon Electronic Data Interchange (EDI) and, in turn, the systems made possible through eXtensible Markup Language (XML). These types of systems have enormous implications on supply chain management, for instance, in the furtherance of trade.

2. What is Information Interoperability?

Information Interoperability is the process by which we transfer and render useful data and other information across systems, applications, or components. For the purposes of this essay, we distinguish between the interoperability as it relates to the information itself (roughly, the "data" and "metadata,") and to the information systems (roughly, the "technology") on which they rely. We take up the concept of semantic interoperability, which helps to explain how certain technologies work together – or fail spectacularly. In our theory of interoperability, these types of interoperability fit into a four-layered "cake" model. Interoperability can be seen at these data and technology layers, but also at what we consider the two higher levels, the human and institutional layers.

There are different ways to achieve interoperability at these multiple levels in the context of information. We call one approach "interoperability by design." Through this approach, companies and organizations produce products (and services) built with the expectation that the products will be able to interact with other products. Industry-led standard-setting processes are another approach, in which different actors agree beforehand to manufacture products according to certain specifications. States can also prompt higher levels of interoperability using a wide range of approaches, including both *ex ante* and *ex post* involvement in the development of information systems. Of course, there are also ways to thwart interoperability or to limit it, which may or may not be desirable in certain cases.

We contend that information-related interoperability, at both the data and the technology layers, is a positive force in the furtherance of trade. We use a series of well-known examples to establish this baseline in our argument, and then turn to thornier matters related to the problems associated with accomplishing interoperability and mitigating its various potential downsides.

3. Information Interoperability in a Global Setting: The Familiar Example of E-mail

Perhaps the most recognizable form of Information Interoperability is electronic mail. Each day, countless e-mails are sent from computers in myriad directions. Some e-mails are sent between two users separated by just a few office cubicles or by a few floors in the same building (or from the living room to the kitchen, in some homes). Other e-mails are sent between users halfway across the earth. These many e-mails can also be sent and received through different media. Users can access their e-mail messages from a mobile device such as a smartphone or from a computer in a library. E-mails may present data in a wide variety of formats, in a message body or as an attachment. E-mails contain links out to other parts of the network, including the World Wide Web. Interoperability is a crucial network design principle at work in the background, making these many transactions possible and apparently seamless, from the perspective of the end-user. A high level of interoperability among and between information systems has made the use of e-mail pervasive on both devices and the world itself.

The viability of e-mail does not depend on a single provider managing trillions of communications each year. Rather, it depends on a set of agreed-upon standards as to how devices, hardware, and software interact with one another. In a stripped-down view of e-mail, Dave Crocker has divided the world of e-mail into two „layers." The first layer is that of the users of e-mail, otherwise called Mail User Agents (MUA). The second layer is the Mail Handling Service (MHS). Essentially, a user sends mail via an MUA. This mail travels across the two layers, and is transmitted by the MHS via the Simple Message Transfer Protocol, or SMTP. The MHS layer then delivers the mail to its destination MHS, after which a recipient-user can view the e-mail using his or her own MUA.[2]

The e-mail message itself follows a set of conventions, which are broadly followed. It begins with a section called a header, which includes relevant transmission dates, a message identifier, and addressing information. The body of the email commonly comprises ASCII text, which is essentially the part of the e-mail that users view when they „open" an e-mail; message texts can be more elaborate, containing images and relying upon HTML and other data formats.

The information contained at each of these layers serves distinct purposes from the perspective of interoperability. The information included in the header helps to ensure that the message gets to the right place in the complex global network. It can also help a technically savvy user understand the context for the message that he or she has received; in this way, the header serves as „metadata" to the data in the message body. These various forms of information – both data and metadata – have been set forward in a series of standards.

An essential part of our argument is that those who created the e-mail system did so in such a manner as to ensure cooperation and collaboration among technologists. The notion, from the start, was to agree upon certain protocols and to use them consistently, without unfair competition sifting into the mix. No one would build an email system for mass distributions without following these basic standards, unless they were seeking to accomplish something quite different than basic messaging.

Another key feature of the highly interoperable e-mail system is that no one seeks to profit from the sending or receipt of e-mail. There is no toll-taker (or intellectual property holder) expecting a payment every time someone uses the basic protocols associated with e-mail exchanges. The complex relationship between intellectual property, innovation, and trade in the information systems context is not so complex in the case of e-mail, given the collaborative approach taken by the initial system's designers. The same can be said of Tim Berners-Lee and the World Wide Web.

Information systems, such as mail servers and email clients, have been designed to make sure that the users of the email system do not need to worry about who made the email client or the email server being used by a business correspondent, whether down the hall or across the world. It ordinarily makes no difference to the users involved. The core concept of interoperability in this sense is the idea of the invisible links between and among systems that allow communications to occur with the least amount of friction possible, often across wildly complex and variable networks and over great physical distances.

Interoperability is crucial in order for this global, nearly free, e-mail system to work. The different layers – both at the data and technology layers, in our cake model – must be able to communicate with each other to ensure that the e-mail properly passes to its destination properly. Moreover, the relevant information at the beginning of each e-mail—in the header—are necessary for the e-mail to reach its destination. The standardization of such a scheme has allowed e-mail to be readily accessed through many different devices, as well as anywhere in the world with sufficient Internet access.

[2] Dave Crocker, *Challenges in Anti-Spam Efforts***,** 8 The Internet Protocol Journal, (2005). *See also*, Dave Crocker*, Internet Mail Architecture*, ISOC, February 2005, http://bbiw.net/specifications/draft-crocker-email-arch-03.html.

4. The Economic Relevance of Information Interoperability

The everyday example of e-mail helps us to see the many ways in which information interoperability is valuable to society in terms of how it can help to foster trade. It is valuable because it facilitates the delivery of information itself: in the e-mail example, the delivery of the data and the metadata involved is an enabler of trade within states and across state boundaries. It brings down costs related to communication (within organizations, between trading partners, and in many other configurations) and it can ensure better, real-time decision-making. It can lead to innovation by fostering more effective collaboration among partners and by enabling other systems to be developed on top of email platforms (consider the integration of Really Simple Syndication, or RSS, into email clients, for instance; or Google's use of advertising alongside free email systems; and so forth). The benefits of this fast communication are hard to overstate. And they would not be as great if it were not for the high level of interoperability among systems.

Interoperability among information systems can vastly improve the transmission of real, tangible products. Take, for example, a stainless steel company that operates in South Korea. The output of this company may seem simple at the outset: they produce and ship units of stainless steel. However, its input and output processes are anything but straightforward. It needs to interact with a large number of suppliers and customers on an ongoing basis with respect to orders and deliveries. It probably will source its ferrochrome from South African miners. It also needs to purchase machinery for production. Moreover, it may need to coordinate with shipping companies for delivery of its product to other areas. Some of its deliveries may go to North American real estate projects. Other shipments may go to giant infrastructure projects deep in western China. In this respect, paper handling can take a very long period of time and is subject to human error. Given the importance of delivery and supply pressures, one wrong move could create significant inventory build-up or even the loss of a valuable customer contract to competitors.

The benefits of e-mail are increased dramatically when combined with business-to-business information and communications systems such as Electronic Data Interchange (EDI). At its essence, EDI is a set of standards that allow computers and machines to process data automatically, with minimal human involvement. The paradigmatic example is order processing: a customer can send a preformatted message, over digital networks, to the South Korean steel company with information about the amount needed, the data by which it is required, the place to which it needs to be shipped, the maximum price they are willing to pay, and so forth, and this order information is automatically entered into the internal systems of the supplier. No humans need to speak to one another; time is saved by virtue of not having to re-enter information from one format and system to another; the likelihood of error in transcription is reduced; and the time to delivery and payment is reduced, to everyone's benefit. It is hard to see why EDI is not desirable in such cases from a trade perspective.

In its original form, EDI was a set of standards created by the Transportation Data Coordinating Committee (TDCC), formed in 1968. Seeing the need to coordinate among shipping, railway, and other common carriers, representatives from these industries set the three core values that the standard had to meet. First, EDI would be able to operate across different computer equipment. Second, the interface would have to be customizable. Third, EDI had to deal exclusively with the formatting of electronic documents, rather than the content or manner of delivery of that information. The standard, growing out of these values, grew into the TDCC Electronic Interchange Standards. These standards were released in 1975. However, its application grew beyond the transportation industries. By the 1980s, automobile manufacturers like Ford and Chrysler interacted with their suppliers using EDI-based systems. Soon, grocery, retail, and pharmaceutical industries adopted these standards.

In recent years, EDI has even incorporated the use of XML to integrate EDI-based systems with the Internet, which has unleashed another flood of benefits. The 1970s flavor of EDI was useful and saved a lot of firms (and, in turn, consumers) a great deal of money, but the advent of digital networks and communications systems meant that this concept could have far greater implications for the way a business runs and communicates. The parties to the transactions could be substantially increased, in particular: no longer were the beneficiaries just enormous players like Ford and its suppliers, which could afford expensive, bespoke communications systems. As the Internet spread, and every company in industrialized countries had easy access to the network and to e-mail, for instance, the value of these advances spread exponentially.

The introduction of EDI and its progeny streamline communication between a firm and its input- and output-counterparties. By standardizing its communications with its suppliers and customers, trading partners can quickly determine optimal output levels and the level of inputs required. In this way, the use of EDI in commerce has markedly changed many industries. With EDI, for example, businesses can more easily employ just-in-time product management. Products can be delivered shortly after the consumer placed her order, avoiding costly overstock for businesses. Management techniques of this sort are no longer cutting edge, but rather expected as a baseline. A high degree of information interoperability has, in turn, allowed for better balancing of industry supply and demand of necessary business inputs.

The story of EDI and XML and their relationship to supply chain management is a familiar one, as is e-mail. The effects of these interoperable systems are simple yet profound and far-reaching. But it is not yet universal in its application. Some fields have yet to develop sufficient technological infrastructure to take advantage of EDI. In other fields, certain vendors insist upon the use of highly proprietary formatting, which reduces interoperability across potential trading partners. In other cases, trade barriers, such as customs and trade regulations, can inhibit the implementation of semantically consistent networked environments. The timely and accurate sharing of information of pertinence to production, inventory, and demand across global supply chain systems is not yet evenly distributed. There is much room for enhancement of interoperability in information systems in the furtherance of trade, even at the fundamental level of EDI-enabled information exchange.

5. Advanced Cases of Information Interoperability and its Benefits for Trade.

The growth of digital networks, coupled with innovation in business processes and related technologies, has made possible more advanced modes of information-sharing that in turn have dramatic benefits for trade. The food business provides an instructive example. Consider the problem of food safety. Imagine a case in which an outbreak of a certain disease occurs in a certain population in the United States. Doctors examining the patients conclude quickly that the source of the problem is food-borne illness. In this particular case, the problem is chicken: a certain amount of meat, distributed at wide scale, carried with it harmful bacteria that made people extraordinarily sick. Public health officials decide to declare a recall of chicken already delivered to customers, and a ban on further shipments, in order to protect the health of the population.

Information systems can provide extraordinary benefits in this scenario. First, systems that can track the source of certain poultry from the point of sale back to the farms where the animals were raised can help to determine the precise nature of the harm to the sick patients. If the incidences of the disease all lead back to a certain region or company producing the unsafe food product, then scientists can track down the poultry that remain for the purpose of quarantine; study of the source of the harm and the nature of the threat to those already sick; and identification of prevention measures to ensure that such outbreaks are less likely to occur in future. These public health benefits are obvious.

The trade benefits of such systems are substantial as well. In such an outbreak, there will no doubt be costs to the flow of trade: public health officials are right to recall infected foods and to restrict the flow of potentially contaminated foods that have not yet reached those who would consume it. But agricultural supply chain information can ensure that the right food is recalled and the right food is stopped from future delivery. From a trade perspective, our societal goal would presumably be to address existing harm and prevent new harms from occurring without destroying food (by blocking the ability to trade it) needlessly. Agricultural supply chain information, which tracks carefully the flow of goods and services from place to place can help to isolate the most likely problem sources without leading to gross over-blocking of the flow of trade (in this case, food).

Information systems in the agricultural field make this type of precision possible. Field information regarding disease and pest incidence is used in viticulture (the growth and harvesting of grapes for the purpose of producing wine), for instance, via tagging. The use of mobile devices in the field, in coordination with the use of these tags, allows for precise geographic coordination and exchange of field. As a result, the winemakers can track data such as humidity, temperature, and other information that might affect the quality and quantity of production. The tagging ensures that data uploaded in the field is automatically and appropriately associated with the vineyard's database, eliminating the risk of human input errors.[3]

In these examples from agriculture and viticulture, the benefits of highly interoperable information systems extend beyond the original EDI-style concept of the 1960s and 1970s. The flow of goods and services can be rendered far more efficient, accomplished at lower cost and higher rates of speed. But innovations in the amount and types of information that can be collected, tracked and shared across supply chains can also help to ensure that public health is protected in such a way that isolates problems quickly, gets information to doctors and the public quickly, and limits the flow of trade in ways that accomplish societal goals without unduly limits the flow of goods and services. Interoperability makes possible this information exchange in fast, seamless ways through complex series of invisible links between and among systems.

C. Challenges to Achieving and Sustaining Information Interoperability

1. Summary

This section discusses two fundamental problems in establishing and sustaining a system of information interoperability. First, we analyze the problem of establishing a system of information interoperability. Using the example of E-Health Records (EHRs), we take up problems of cost and coordination that so far have bedeviled all attempts to create such a system. Next, we focus on how to sustain interoperability once it has been achieved. In particular, we focus on the challenges associated with information preservation as file format types change over time.

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[3] Carlos R. Cunha et al., *The Use of Mobile Devices with Multi-tag Technologies for an Overall Contextualized Vineyard Management*, 73 Computers and Electronics in Agriculture 154 – 155, 162 (2010).

2. Methods of Accomplishing Interoperability and Interop-Related Problems

Electronic health records (EHRs) offer a multi-faceted, instructive example of the range of ways to accomplish interoperability in information systems and the challenges associated with them. The provision of health care is a multi-billion dollar business in many countries around the world.

Increasingly, the health care business is an information business. Information about a patient or a disease or a drug holds intrinsic value; it also holds value insofar as it can be shared among multiple actors, in many cases increasingly so the more people who can access that information in responsible ways.[4] At the same time, personal informational privacy in the context of health care is a crucial topic: people have rights in health-related information that do not attach in other trade-related contexts. The business of health care is often the business of managing very sensitive information about large numbers of people. Interoperability in this context is both powerful and a bit dangerous.

Many countries, especially in Europe, North America, and East Asia, have sought to put in place large-scale EHR systems. But the process has not worked as planned in virtually any setting; it has proved far more difficult than anticipated, across the board. The UK undertook a process of creating an EHR system during the administration of Tony Blair that has cost billions of pounds and continues to this day. Australia has introduced the National E-Health Transition Authority to oversee and analyze the shift to EHRs. Two United States presidents – Barack Obama and George W. Bush before him – have pledged to create a reliable system of EHR by 2014. A proposal for an international standard for EHRs has been floated as well, which plainly could have benefits for international trade in the field of health information.[5]

The theoretical advantage of highly interoperable information systems is clear. Easy access to health records electronically will make medical records more reliable to health care providers; cut down on heavy usage of paper; and enable the creation of more accurate and comprehensive records of information about patients and societies, among many other benefits. But the way to get there is far more complex than it may seem at the outset. The barriers to adoption of an optimal EHR system are many. In this section, we discuss these barriers to achieving information interoperability and some problems that will arise once we have established such a system.

While the benefits of electronic health records systems are clear, the problems of creating and maintaining such a system are nearly as numerous. The transition to a digital system is easier said than done. The complex system of institutions and people built to support the storage and transmission of analog medical information requires an enormous amount of coordination to change. The US Department of Health and Human services estimates that around 700,000 entities in the United States alone handle health-care-related information. Such entities include hospitals, doctor offices, medical equipment providers, and pharmacies. Each has its own system of information storage.

This shift to EHRs is expensive. Hospitals, for instance, fear spending millions of dollars to shift its records into an EHR-compatible system, only to realize that its partners did not yet have a system it could interoperate with. A related fear: given the fast rate of development of technology systems, an EHR system might need to be scrapped after only a few years to keep up with new developments in the field. This certain (if not "planned") obsolescence of EHR systems, of course, is a good thing for software and service providers who will profit from not

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[4] *See* Joseph Yeh, *Electronic Medical Records May Save US $1.7 Billion Annually in Taiwan*, McClatchy Tribune Business News, August 10, 2011.

[5] *See* Donald T. Mon, *Model EHR: Status and Next Steps for an International Standard on EHR System Requirements*, 81 Journal of AHIMA, March 2010 at 34.

just initial sales but also from the updates, but it is a problem for health care companies and a barrier to initial adoption.

In addition to cost, a barrier to interoperability that any state must address is the literal engineering challenge of making systems work together. Some systems are hard to make interoperable as a matter of systems engineering (or, in the analog world, physics). There are simple interop problems, such as the example of making the fuel pumps work together with the fuel tanks of cars in the gas station example. More often, though, interop problems arise in the context of highly complex systems that require intricate feats of engineering to make work. In the case of EHRs, the challenge is substantial. There is a great deal of complexity involved in terms of the number and types of existing files that need to be brought together. There can be no interoperability of complex information systems, in the health care system or otherwise, without clever engineers.

These engineering challenges are a close cousin to the problem of legacy systems. In most cases where we desire interoperability, as in the case of health care, we are not working from a blank slate. Someone has built information technology systems over a period of time, for instance, that run day-to-day operations, say, of a hospital. The notion of transitioning everyone from a thousand different systems to one single system is hard to contemplate. Interoperability itself can play a role as a barrier to further interoperability, in a curious way. One problem with legacy systems is that lock-in can ensue where a suboptimal degree of interoperability exists or where previous-generation systems are highly interoperable. Sometimes it is hard to take a break from existing systems and start again. This is why the starting point is so crucial.[6]

The complexity of the system overall is another essential consideration. The health care system is so big and complex that it is impossible to capture the entire universe in a single, conceptual frame. Some systems are so big and complex that no one can see the whole of the elephant, as the saying goes; one can see the trunk, the legs, or the tail, but not the whole animal at once.

This problem of systemic complexity recurs through the most interesting interop problems, including EHRs. Much of the time, interop occurs largely via market forces and over time. We as societies have a hard time understanding the effects of the complex interactions between large systems, as the case of financial systems interoperability and the crisis of 2008 – 2010 shows, until after the fact. In these instances, there is no master planner. Much in the way of interoperable information systems is emergent, whereby small-scale interop decisions lead to a much broader, interoperable environment over time. This piece-meal strategy may not be completely desirable, but it is very often how it works. Interop can come to pass in a top-down fashion, by fiat. But in the case of the most complex systems, it is more likely to come to pass in an emergent fashion where we see it only after it has happened. Small and medium-sized decisions to render systems interoperable lead to large-scale, interoperable systems. In other words, a consistent series of incremental innovations can lead, over time, to radical innovations. This quality of large-scale, emergent interoperability poses a special difficulty for any centrally-planned effort to remake the health information technology system given the complexity of the system over all.

The most significant barrier between where we stand and a system of interoperable EHRs is not, however, about cost, engineering, lock-in to legacy systems, or even the complexity of

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[6] The case of air traffic controls is the best example of this problem. The system of air traffic control has developed over time into a highly interoperable system, but it is also a system in need of innovation. The fact that the pieces work together so completely, and support such a crucial ongoing function, has led to a kind of lock-in that makes innovation within the system very difficult to manage.

the system as a whole. Each of these presents a serious challenge, but none is insurmountable. The largest barrier has to do with the way in which firms are competing in the marketplace to develop and use EHRs. It is the management of these many firms that is the biggest challenge to establishing optimally interoperable EHRs.

This barrier to interoperability in EHRs is a particular *form* of competition in the marketplace. Competition, in ICT systems and otherwise, is a good thing in general. It is desirable to have a level playing field where everyone has a roughly equal shot at coming up with an innovative approach to solve a hard problem like EHRs. At the same time, competition of a sort that is grounded in a winner-take-all philosophy is problematic from the perspective of interoperability.

EHR systems are being developed and marketed by private sector players, who are competing in ways that often work at cross-purposes with the shared goal of optimally interoperable EHRs. If firms competing in the EHR space see a large pot of gold at the end of the rainbow for the firm that comes up with the single standard around which everyone else's solution must be built, then their incentive is not to cooperate on an interoperable standard. As in the case of most other information industries, there are strong network effects—the more users are on one particular system, the more valuable it is to other users. In market competition, the proliferation of firms advocating for their own proprietary system of EHR has in effect hampered the growth of a clear unified standard. The incentive of legacy service providers of information systems in the health care system is to sell as many instances of their own software as possible, not necessarily to help to create a new, interoperable platform that could favor new market entrants who are able to build systems from scratch.

The mechanisms by which legacy service providers compete may vary. A simple approach is simply to fail to allow their systems to interoperate completely – i.e., to the point of "substitutability," as Professors Kenneth Mandl and Isaac Kohane have argued – with those of others.[7] In the case of EHRs, the issue is more likely to be that market players allow a limited, but not optimal level, of interoperability between their system and the systems of others. The challenge is to get from this limited level of interoperability to something closer to optimal levels of interoperability.

It makes sense to pause at this point in the analysis to introduce the role of intellectual property as both an enabler and a constraint in terms of developing interoperable information systems. In some fields, the use of intellectual property rights (IPRs) can block potential developers. By creating such "patent thickets," competitors can block prospective entrants and actual competitors by asserting patent infringement actions. While IPRs can help promote innovation in some cases, they can also be used in such a way as to block competitors and to hamper the development of highly interoperable systems. We have found little in the way of evidence, in conversation with experts or in the scholarly literature, for the proposition that IPRs are currently serving an adverse function with respect to interoperability of EHRs. More so than IPRs, the technical criteria of regulations for health care information themselves may prove to be a constraint to widespread interoperability in EHRs.[8]

3. Problems that Emerge Even When Systems are Made to Interoperate.

Even if we were able to make information systems optimally interoperable in the health care

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[7] Kenneth Mandl and Isaac Kohane, *No Small Change for the Health Information Economy*, N Engl J Med 2009; 360:1278-1281.

[8] *See* Wieland, Medical Laboratory Observer, April 2011, *What is the Office of the Inspector General's (OIG) role in electronic health records (EHR)?*

system, we would still face problems. A simple problem, advanced by critics, is that it is doubtful to what extent a single universal system of medical recording can capture all the necessary information for a medical patient. In this sense, the complexity of the information itself may make the system hard to bring to fruition.

More important, however, security and privacy concerns also tend to give health care providers pause. Assuming a single interoperable system of EHR arises, there is a serious threat that electronic medical records may be stolen. While the US government has pushed for legislation to ensure that EHRs are not readily accessible by unwanted users, the idea of allowing once personal information to be accessed anywhere in the world has made EHR slowed EHR development significantly.

Problems may arise, too, at higher levels in our cake model, above the technological and data interoperability layers. Language interoperability—or semantic interoperability—is particularly challenging in cases where data are exchanged among a diverse group of people, organizations, and IT systems. In the context of EHRs, the basic idea is that healthcare providers have access to computerized medical records that typically contain a lot of data from a variety of relevant sources. Much of the data has been put into text form through the transcription of dictated reports, for instance using speech recognition technology, or based on direct entries by healthcare providers.

Such textual data is relatively easy to process for human beings, but can be a challenge for computer-based analysis, search, summarization, and graphic presentation. Take a simple example: for humans, "heart" and "cardiac" are terms with essentially the same meaning; for an EHR system, however, they may be two unrelated terms.[9] Industry alliances and standard setting bodies have started to work on classifications of medical terms to ensure semantic interoperability for health data. We have seen similar attempts at developing so-called ontologies in other disciplines, for instance in the field of legal informatics. This additional challenge demonstrates the types of problems associated with interoperability that are unrelated to the data or the technology layers, but rather work at the human and institutional levels. The information may flow seamlessly across systems, but may not prove to be useful to the health care providers or others in the system who need to use it.

The biggest problem of all in terms of creating a more efficient, productive health care system may well have nothing to do with technology in a strict sense, but rather be a cultural problem. Doctors and those who work in health care companies often fear change, like anyone else, and do not wish to adopt new systems for any number of reasons. This cultural resistance operates at the human and institutional layers of the interoperability "cake" model. Cost is an important factor, of course; no one wants to pay more than what they perceive to be their "fair share" of the start-up costs to establish a highly interoperable system of health care information. These cultural concerns and struggles may be the source of the highest barrier to creation of a trade-enhancing, optimally interoperable system of health care information.

There are many lessons about interoperability to be gleaned from the EHR example. The most obvious is the difficulty of attaining interoperability in the most complex information-related systems, despite the plain benefits to trade and to society at large of getting the job done. Another is the range of approaches that one might take to accomplishing an optimal level of interoperability. In the case of e-mail or EDI, market players worked together to accomplish interoperability without much involvement of the state. In the case of EHRs, an optimal level of interoperability has not materialized through private-sector-led efforts, and the involvement of the state is plainly necessary. And even when we accomplish

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[9] *See* Peter J. Groen & Marc Wine, Medical Semantics, Ontologies, Open Solutions and EHR Systems, available at http://www.hoise.com/vmw/09/articles/vmw/LV-VM-09-09-6.html

interoperability at all levels, problems may still remain to be addressed, in particular the potential adverse impact on individual data privacy and security. A final problem remains to be examined in the section that follows: the challenge of maintaining interoperability over time, which will factor substantially in the EHR context as well, after the baseline has been established.

4. Interoperability Over Time: From Library Books to Corporate Records

Interoperability is useful to trade as soon as it is established in information systems. But an optimal level of interoperability must also be maintained, and ideally adjusted according to ongoing needs, over time. This maintenance process can be as expensive and as politically charged as the development of interoperable systems in the first place. Information Interoperability cannot last forever—it must be constantly renewed.

The problem of interoperability over time, and its importance to trade, can be seen clearly in an unlikely context: libraries. Librarians are experts at working with information in a variety of formats. Librarians also face the problems of interoperability in information formats over time in ways that have great relevance for those interested in trade-related problems.

With the growing shift to digital, and sometimes online, materials as the dominant form of information delivery in some fields, the preservation of interoperability levels, and compatibility of formats in general, is a constant concern for librarians. The analog era was a simpler time for librarians. At a high level, as they built their collections, they determined what information ought to be included; they found a way to buy a physical copy of the information; and they brought it to a physical location where it could be shared, one copy at a time, with their patrons.

In the digital era, the challenge facing libraries is in part the same and in part different. The part that is the same is that librarians still need to determine what information their patrons need and then have to do a great deal of work to ensure that they can provide timely access to it. The invisible processes that make excellent librarianship possible – like the creation and use of metadata, for instance – remain, if not become more important in a digital era. The different part is that the material is not primarily in a single (analog) format and often never "arrives," to be placed on a shelf and handed over to a patron for a time-limited period, until it is returned.

Along with user preferences and changes in publishing models, cost is also a major factor in the push toward digital formats. Libraries cannot afford to buy both the hard-copy and digital forms of all material, as much as they might like to do so. The cost of maintaining a collection of both hard-copy and electronic copies of materials, much of it serialized, pushes libraries to rely heavily on digital formats. This has a number of benefits. It saves precious space for other books, and it also allows users to access them more easily. However, this method saves on other costs. It is too expensive to purchase both the hard-copy form of all the materials a librarian needs for patrons as well as access to the digital files in perpetuity. Space comes at a premium, so librarians have to make hard choices about what to keep on the shelves on-site. Most users in many libraries prefer to access the material online, given how convenient it is to just find the paper through a browser.

The trend in information is toward a proliferation of formats over time, not a consolidation. Media is becoming more and more diverse. There is no one standard e-book format. Want to read an e-book? It depends on what kind of e-reader you have. The reader itself may not be able to read .azw (for Amazon), .pdf, .aeh (for Arghos), .djvu (for DjVu). Even outside of text-based information, users still face a large growth in differing formats. Digital video requires a number of players. Such players could be Flash-based (.flv, .swf), Quicktime-based (.mov), or playable by Windows Media (.wmv). There are others such as DivX, Xvid, and so forth.

The problem for libraries is also a problem for trade. Imagine that a large amount of information is stored in a particular file format in 2011. In 2051, the formats of that type of information have changed a half-dozen times. The way in which one might learn, say, about order histories and trends over time, in a corporate setting, might be akin to trying to read a Word document that resides solely on a 3 ½-inch floppy disk today. A possible solution to this problem is to keep versions of every computing system ever created so that old files can be re-rendered. Another would be the belt-and-suspenders approach: all information could be produced both in a digital format and in a hard-copy format, so that new digital formats could be reproduced from the hard-copies when needed. Both of these processes seem needlessly expensive and cumbersome—and implausible.

A better idea would be to ensure ex ante that the data would be readable even after a given file format were to become obsolete. This regime would work roughly as follows. First, publishers of information would accept that data be rendered in one of a series of acceptable formats. These formats would be subject to a set of rules requiring backward-compatibility. The data would be placed into a shared (say, between trading partners), cloud-based environment at an agreed-upon location with an agreed-upon naming convention. The work would be registered with an independent body, such as a copyright office, with metadata associated with it. Depending upon the importance of the information, a hard copy of the data could be put into a central depository, as a sort of "insurance policy." (Consider the difference between a copy of a corporate charter, with original signatures, and the notes from a meeting between two suppliers as they hammer out an agreement; the first might merit inclusion in a hard-copy repository, while the notes might harmlessly fade away in the event of emergency.)

Note however, that there are additional complexities here: international harmonization of this process, IP rules that the regime would implicate, and general security concerns since the regime distributes the data to a number of different places. There are many problems that might arise from a collective failure of responsibility. The process of preservation requires economic cost, and without clearly defined commitments from private actors, the entire regime may not work. In the library world, there are many different types of approaches that might offer useful lessons for the world of trade. These data preservation initiatives include: LOCKSS (Lots of Copies Keeps Stuff Safe), NEDCC (Northeast Document Conservation Center), UDFR (Unified Data Formats Registry), PRONOM (National Archives of the United Kingdom's technical registry), and Portico, just to name a few. However, there are two large drawbacks to such systems. Firstly, the work may be somewhat duplicative. Secondly, there is the risk that increasingly treasury-conscious organizations will be less and less willing to spend money on these projects in the long run.

One of the core problems associated with interoperability over time is that many players will have to collaborate in order to maintain sensible systems. The possibility of collective action problems arising and persisting is high. In the context of corporate record-keeping, the players include those who make software (think of Adobe, the maker of PDFs, and Microsoft); those who make hardware; those in their respective supply chains; those who store information (Iron Mountain, for instance, or libraries); the relevant states and their government agencies; and the many market players that rely upon these complex and integrated systems. No one player can ensure interoperability over time of information systems; it will be increasingly necessary to collaborate, in a context where the overall goal is shared but the incentives to play any given role are varied and sometimes murky.

Our argument comes full circle when one considers the importance of this same concept of interoperability over time with respect to EHRs.[10] It is one thing to be able to establish a system of interoperable health information on day one; it may well be quite a harder challenge to ensure that we are able to re-use the information that is in a record, first created for a baby born today at her pediatrician's office, when she shows up in a geriatric ward. This example is a bit extreme: it is hard to imagine why the geriatrician would need to know what the pediatrician thought eighty years before. But the importance of accessibility of information and information systems over time, in the interest of trade, as well as other social goods such as health, is plain.

D. Conclusion

In this essay, we have examined a wide range of facets and roles of interoperability in the context of information and information systems in the furtherance of trade. It is plain that optimal levels of information-related interoperability has much to offer from the perspective of trade. These benefits range from the simple notion that trade can be rendered more efficient and less costly through the use of email and EDI to the more complex, where innovative systems such as RSS, XML, mobile and cloud-based services build upon the platform of basic information systems to provide enhanced benefit.

We fit these multiple types of interoperability into a framework characterized as our "cake model," which helps to demonstrate that interoperability is not solely about making technology systems work together at the level of application programming interfaces (APIs), for instance. It is necessary, but not sufficient, to accomplish interoperability at the technology and data layers in information and information systems. We must also pay attention to human and institutional aspects to interoperability, including culture, semantics, and organizational behaviors.

The relationship between interoperability in information systems and trade is complicated, though, insofar as the means to accomplish interoperability is not always straightforward; interoperability can bring with it new problems; and interoperability must be maintained over time. Market actors, along with states, must work together to accomplish certain kinds of interoperability that serve to benefit trade at large; these entities must work as partners in ways that are novel and not always obvious at the outset. The best approach to optimal levels of interoperability must be assessed on a case-by-case basis, which requires flexibility and foresight. The problems that high levels of interoperability can bring with it, such as threats to privacy and security, need to be mitigated through thoughtful design and potentially regulation. The maintenance of interoperability in information systems over time may prove as hard and costly as the establishment of interoperability in the first place.

As a general matter, the benefits of interoperability to trade, among other public interests, especially in an increasingly digital and networked world, outweigh the costs associated with meeting these many challenges. We argue that interoperability should be considered to be a worthy public policy goal. However, interoperability is not important for its own sake; it is useful because it can help us to accomplish other desirable social outcomes, such as trade. Based on previous studies and anecdotal evidence, we conclude that interoperability in information and information systems is an important means towards innovation, competition, and economic growth that public policy makers should consider and use systematically and strategically.

In the examples that we have used in this essay, many of the systems involved are primarily

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[10] Elizabeth Gardner, *Preserving EHRs: Time to Worry?* 19 Health Data Management, June 2011, at 44.

national, rather than international in nature at the outset, such as EHRs and agricultural food safety rules and processes. Others have clear international qualities to them, built into their design, such as e-mail, EDI, XML, and RSS. An area for further consideration in research and design would be to take up the hard question of whether such international approaches to interoperability are best driven by the private sector – which appears to have been the case in the examples on which we have relied in this paper – or whether states and IGOs may play a constructive role in helping to achieve optimal levels of interoperability in information and information systems in the furtherance of international trade.

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