WPS4466

Policy Research Working Paper 4466

On SARS Type Economic Effects during Infectious Disease Outbreaks

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The World Bank
East Asia and Pacific Region
Chief Economist's Office
January 2008

Policy Research Working Paper 4466

Abstract

Infectious disease outbreaks can exact a high human and economic cost through illness and death. But, as with severe acute respiratory syndrome (SARS) in East Asia in 2003, or the plague outbreak in Surat, India, in 1994, they can also create severe economic disruptions even when there is, ultimately, relatively little illness or death. Such disruptions are commonly the result of uncoordinated and panicky efforts by individuals to avoid becoming infected, of preventive activity. This paper places these "SARS type" effects in the context of research on economic epidemiology, in which behavioral responses to disease risk have both economic and epidemiological consequences. The paper looks in particular at how people form subjective probability judgments about disease risk. Public opinion surveys during the SARS outbreak provide suggestive evidence that people did indeed at times hold excessively high perceptions of the risk of becoming infected, or, if infected, of dying from the disease. The paper discusses research in behavioral economics and the theory of information cascades that may shed light on the origin of such biases. The authors consider whether public information strategies can help reduce unwarranted panic. A preliminary question is why governments often seem to have strong incentives to conceal information about infectious disease outbreaks. The paper reviews recent game-theoretic analysis that clarifies government incentives. An important finding is that government incentives to conceal decline the more numerous are non-official sources of information about a possible disease outbreak. The findings suggest that honesty may indeed be the best public policy under modern conditions of easy mass global communications.

This paper—a product of the Chief Economist's Office in the World Bank's East Asia and Pacific Region—is part of a larger effort in the Region to better understand the economic aspects of infectious diseases, with a view to developing more effective policies to alleviate their human and economic costs. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at mbrahmbhatt@worldbank.org.

Produced by the Research Support Team

On SARS Type Economic Effects during Infectious Disease Outbreaks

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1. Introduction

Recent years have seen a renewed interest in the surveillance and control of infectious diseases, as well as in their importance as a problem in economic development. The revival of attention follows the emergence of many new infectious diseases - more than 30 in the past 25 years – including HIV-AIDS and, more recently, severe acute respiratory syndrome (SARS), the emergence of drug resistant strains of old diseases, and the return of concern about old threats that had never gone away, such as pandemic human influenza. Interest in the economics of infectious diseases has also increased with recent experience of the large economic costs they can entail, for example those arising from the enormous illness and mortality associated with HIV-AIDS in developing countries, or the short-lived but severe economic shocks that occurred as a result of SARS in 2003 or the plague outbreak in Surat, India, in 1994, disease outbreaks that, unlike HIV-AIDS, in the end caused relatively little illness and death.

Infectious disease events of the type exemplified by Surat and SARS are interesting because they do not fit too well within the standard "cost of illness" approach to measuring the economic impacts of disease. In this paper we stand back to look at recent work in economics that helps place the type of effects at work in such episodes into a broader conceptual and analytical framework that also encompasses the cost of illness approach. Such a framework should be helpful in deepening our understanding of the links between infectious diseases, individual choices and behavior, public health policies, and the economy. Ideally it should also help improve understanding of the constraints and tradeoffs facing public health policy makers, as well provide some insight into ways to improve public health policies.

Section 2 of the paper outlines the standard cost of illness approach, which focuses on the opportunity cost of resources that are consumed or lost as a result of disease, whether these are direct costs, such as the costs of medical treatment, or indirect costs, such as loss of productive capacity due to illness and death. This approach is the backbone of many recent studies of the economic costs of HIV-AIDS, for example. Section 2 then briefly reviews the Surat and SARS events as exemplifying aspects of infectious disease outbreaks for which the standard approach seems inadequate. The economic essence of these events appears to reside in *costs of prevention*, in one form or another. Thus the main economic effects arise from the uncoordinated and sometimes panicky efforts of millions of private individuals to avoid becoming infected, for example by fleeing from the area of an outbreak or by reducing their contacts with other people. Such effects are sometimes aggravated by the information and risk communications strategies pursued by governments in affected countries, as well as by the often excessive trade and travel restrictions imposed by governments in other countries, which are justified as a way of preventing the international spread of the disease.

Section 3 suggests that recent work in economic epidemiology may provide a natural framework for analyzing infectious disease events like SARS, Surat or a potential human influenza pandemic. The key intuition of this approach is that self-interested, forward looking individuals adapt their behavior to take account of the prevalence of a disease and the threat it poses to them. These changes in behavior will differ according to the disease, but they will generally have both economic and epidemiological consequences, in the latter case by feeding back into the rate of new infections and disease prevalence. We set out a simplified version of a standard S-I-R epidemiological model to illustrate how such models can be adapted to reflect choice of preventive behaviors by utility-maximizing individuals. Section 3 then focuses on the primordial facts of high uncertainty and highly imperfect information that typically prevail during infectious disease outbreaks. One implication of these facts is that the nature of protective changes in behavior will depend critically on people's subjective judgments of probability about their uncertain environment, for example on the probability that an outbreak has occurred, or on the conditional probability that they will become infected given a certain level of protective action.

How do people form these subjective probabilities? A useful benchmark assumption is that of rational expectations, that people do not make persistent and systematic errors about the key probabilities governing their environment. On the other hand research in psychology and behavioral economics over recent decades amply demonstrates the presence of substantial biases in probability judgments in many contexts. Recent theoretical work on information cascades and herding behavior also suggests the possibility that in situations of imperfect information people may rationally look at the behavior of others as a source of information, and that this procedure can lead large numbers to jump to the same erroneous conclusions and sub-optimal decisions. It seems quite likely that under the conditions of high uncertainty, poor information, rapid change and emotional stress that prevail during an infectious disease outbreak, individuals could well arrive at significantly biased subjective assessments on key factual issues, at least for a time, leading them to panic and take less than optimal decisions, resulting, in the aggregate, in an excessively high cost of private preventive actions. Section 3 looks at public opinion surveys taken during SARS which provide suggestive (though not conclusive) evidence that people did indeed at times hold excessively high perceptions of the risk of becoming infected with SARS, or, if infected, of dying from the disease. However some survey evidence from SARS also suggests that disease risk perceptions are quite sensitive to new information, and that people are constantly trying to update and improve their subjective probability assessments. This makes sense, since being consistently wrong can be expensive in an infectious disease setting.

Section 4 looks more closely at the role of information and communications in public health policy. The likelihood that people can and do make economically costly mistakes about how best to protect themselves from infectious disease suggests a rationale for public information and risk communication strategies that help reduce unwarranted panic by providing the public with more accurate and timely information. The need for transparency in public risk communications strategy is widely promoted nowadays. Why then is it that not infrequently a government's initial impulse is to try and *conceal* information about an outbreak from the public and from international bodies like the WHO? To achieve more transparent information strategies it is first necessary to understand the incentives facing governments. In the early stages of a limited disease outbreak there may be considerable uncertainty about whether it will turn into an epidemic or simply fizzle out, so that there is an incentive for the government to simply "wait and see", especially if an announcement by the government might itself start a panic or provoke the kinds of severe trade and travel restrictions that were imposed on India during the 1994 Surat plague outbreak. Against these possible benefits must be set the increased risk of the outbreak turning into a full blown epidemic because of secrecy and delays in launching public health measures or in calling for international assistance.

Recent work that employs a game-theoretic framework to analyze the government's choices helps clarify the conditions under which the government reports or hides information about a disease outbreak. An important finding is that the incentives to hide information decline when there is an increase in non-official sources of information about the outbreak, for example via cell phones or the internet, and a consequent increase in the probability that the country will be subjected to pre-emptive sanctions by other governments (or by its own public) despite its efforts at concealment. Indeed efforts to hide information may only undermine the government's credibility with its own public and with international partners, fostering even greater uncertainty, panic and foreign sanctions. Even putting aside ethical considerations and using only a narrow cost-benefit calculus, it seems that the modern environment of easy mass communications within and between countries increasingly makes honesty the best policy in public risk communications. A transparent and credible public information strategy is likely to be the best way to minimize unwarranted panic and, indeed, to mobilize the public as a partner in controlling the disease outbreak. We briefly look at the information strategy adopted by Singapore as an example. Section 5 of the paper provides concluding remarks.

2. Economic Costs of Disease – Questions from SARS and Surat

In recent years a number of epidemic disease outbreaks have generated severe economic effects that do not easily fit into the standard approach to measuring the economic costs of disease. The outbreak of plague in 1994 in Surat, India and the 2003 SARS outbreak in East Asia are examples. To highlight the distinctiveness of these episodes this section first outlines the standard "cost of illness" approach to measuring the economic impact of disease. It then briefly reviews the Surat and SARS events, pointing to aspects for which the standard approach seems inadequate.

The Cost of Illness approach

The cost of illness approach focuses on the opportunity cost of resources that are consumed or lost as a result of disease. These costs are of two types. Direct costs are resources used to treat or cope with the disease, for example expenditures for medical care and treatment, such as the costs of hospital care, physician services, nursing, drugs and so on. Indirect costs comprise the present and future costs to society from morbidity, disability and premature mortality, in particular losses of output caused by reduced productivity or death of workers.[2]

[2] US EPA (1991-ongoing) and RTA International (2006) discuss the cost of illness methodology and provide empirical cost estimates for various diseases. A different though related method is the Burden of Disease approach, which uses the Disability Adjusted Life Year (DALY) measure. DALYs measure the

Examples of economic analyses based on this approach include Meltzer, Cox and Fukuda (1999), which develops monetary estimates of the direct and indirect costs of an influenza epidemic in the United States. The cost of illness approach also provides the basic conceptual framework in many studies analyzing the economy-wide costs of HIV-AIDS. Recent work in this area includes sophisticated analyses of the inter-temporal general equilibrium effects associated with the direct and indirect (illness and death) costs of HIV-AIDS: for example, reduced private and public saving and investment due to resources being diverted to medical treatment for the sick; reductions in the size of the effective labor force due to illness and death, as well as declines in productivity of the remaining labor force, with differential impacts across sectors; falling human capital due to reduced transmission of knowledge and capacity from missing parents to orphaned children.[3]

Episodes like the plague outbreak in Surat and SARS are particularly interesting because they do not fit the standard model but still involved large economic effects. These effects did not arise principally from direct medical costs or from actual sickness or death, which, thankfully, were very limited. Official estimates counted only 52 suspected plague related deaths in Surat. The WHO's final tally for SARS is 8,096 probable cases worldwide, resulting in 774 deaths. The major economic effects in these events arise instead from the uncoordinated efforts of millions of private individuals to avoid becoming infected. Costs of prevention are at the forefront here. Such effects are sometimes aggravated by erroneous public risk communications strategies and by the trade and travel restrictions imposed by governments in other countries, actions that are often excessive but which are rationalized by the need to prevent the international spread of the disease.

The 1994 Plague Outbreak in Surat

The first recorded sign of a plague outbreak in the western Indian city of Surat occurred on September 19, 1994 when a patient was rushed to the New Civil Hospital with high fever, soon followed by two more, all being given routine malaria treatment. By September 20 the hospital had admitted seven patients with 'pneumonia-like' symptoms. Other hospitals reported patients with similar symptoms. By September 21 seven patients had died citywide. A lack of adequate diagnostic testing facilities led public hospital doctors, conferring with private sector colleagues, to rely on sensitive clinical diagnoses, without waiting for laboratory results, and to conclude that there had been an outbreak of plague (Cash and Narasimhan 2000).

At this point there occurred what the Center for Science and Environment in India describes as a "crisis of confidence among the public authorities", which "was one of the most striking features of the Surat epidemic" and which, in combination with the "lack of trust of the people in the government", contributed greatly to the panic that swept the city (CSE India 2006). An initial attitude of skepticism or denial evolved into confusion as

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numbers of years of potential healthy life that are lost due to premature death, poor health or disability. (Lopez et al, 2006).

[3] See for example Drouhin, Touze and Ventelou (2003), Gaffeo (2003) and Bell, Devarajan and Gersbach (2004) and references to the extensive 'Economics of AIDS' literature therein.

different officials made contradictory statements about the nature of the outbreak, the number of infections and deaths and whether and when quarantine would be imposed. City administration tottered as half the civil work force reported sick. Members of the public were thrown back on word of mouth, rumor and exaggerated media reports in making their own assessment about the likelihood of a plague outbreak and of the danger of infection to themselves and their families. Given the lack of accurate information about actual overall infection and fatality rates, the public's perceptions of risk appear to have become anchored on the most vivid and frightening aspect of rumors and media reporting, the high mortality among reported hospital cases. "From September 19-22, 1994, there were three straight days of chaos at the Surat railway station and the bus stand. People clambered on any and every vehicle that could take them away… More than half of the physicians departed as well." (Tysmans 1995). By September 26 it is estimated that up to a quarter of the city's 2.2 million people had fled the city. Panic spread to other major cities. (Ramalingaswami 2000).

The economic repercussions of the Surat outbreak were immediate and severe. Businesses in Surat city lost an estimated $260 million in trade due to the negative demand shock caused by the panic. Many countries in Asia and the Eastern Mediterranean stopped flights to and from India. The UAE suspended cargo transshipments from India, a major blow to Indian exporting capacity. Many countries embargoed imports of foodstuffs, textiles or other goods from India. The loss of exports was estimated to be at least US$420 million at 1994 prices. All this occurred despite a request from the WHO that no trade or travel restrictions be imposed on India. In addition, tourist bookings fell by at least 2.2 million. Overall economic losses associated with the outbreak were put at over $2 billion. (Cash and Narasimhan 2000, Susarla 1996).

The 2003 SARS Epidemic

The first cases of severe acute respiratory syndrome (SARS) are thought to have occurred in China's Guangdong province in November 2002. In his narrative of events Huang (2004) notes that local health personnel reported to superiors about the new disease in mid December 2002, but, given some restrictions on the release of public health-related information, it was not till February 2003 that Guangdong health officials made a public announcement about the disease. The first nationwide alert was issued in early April and a coordinated and effective campaign to combat SARS in China began in mid April.

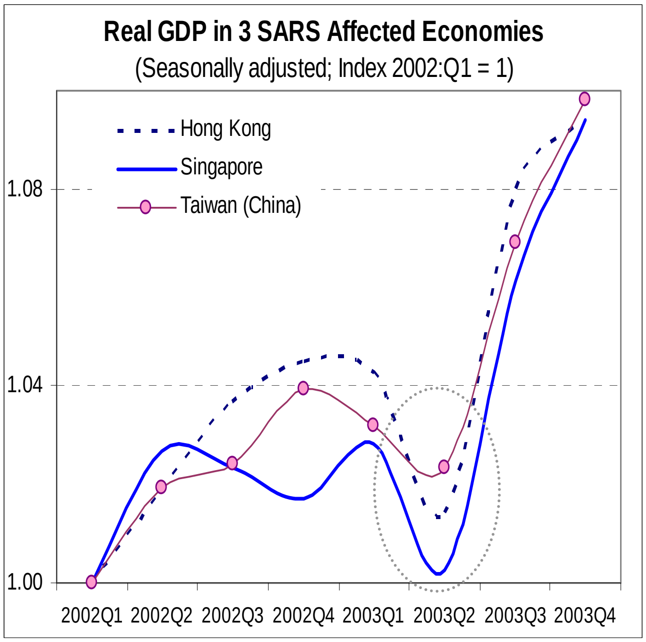
Word of mouth about the disease spread quickly both inside and outside China, a process facilitated by widespread access to cell phones and the internet. It is estimated that "billions" of cell phone text messages with some reference to the disease were sent in the country. According to Pomfret (2003a), from February 8 to 10 the SMS text message "There is a fatal flu in Guangzhou" was sent 126 million times in Guangzhou city alone. Pharmacies were stripped of antibiotics and flu medications. Meanwhile, according to the WHO, the first probable case in Hong Kong occurred on February 15, with an escalation from late February. Infected travelers from Hong Kong subsequently started outbreaks in Vietnam, Singapore and Canada, touching off a world wide career that ultimately affected some 32 countries and territories.

Within China, the first recorded case in Beijing occurred on March 5. The numbers of probable cases in Beijing began accelerating at the beginning of April, peaking at over 100 per day in the latter part of the month. (Liang *et al* 2004). The Beijing local government sharply revised up the SARS caseload in the city from 37 to 339 on April 19. (Beech 2003). In another week, even this number tripled. On April 23 reports from the scene described thousands of people at Beijing West rail terminal attempting to flee the city. By April 26 journalists were estimating that a million people (a little under 10 percent of Beijing's population) had left the city. (Pomfret 2003b). Highlighting the gravity of these developments, Huang (2004) argues that "The SARS epidemic was not simply a public health problem….it caused the most severe socio-political crisis" in many years.

The most significant economic impacts from SARS occurred in the four East Asian economies with the highest number of probable cases: China, Hong Kong, Taiwan (China) and Singapore. The major source of the economic impacts experienced in these economies were the large, though short-lived, negative demand shocks induced by the efforts of individuals to avoid becoming infected, leading to steep reductions in foreign and domestic tourism, as well as reduced domestic traffic for services sectors such as retail stores, hotels, restaurants and transportation. Lee and Mckibbin (2003) also point to the possibility of increases in business costs due to supply side disruptions and of increases in economies' risk premiums in international capital markets. However it was the negative demand effects that predominated in practice.

Hai et al (2004) report on a survey of businesses in Beijing carried out on April 18. Tourist attractions, exhibitions and 4/5 star hotels reported a loss of revenue compared to a year earlier of around 80 percent, while travel agencies, airlines, railways, restaurants, retailers and taxis reported declines in revenue of 10-50 percent. Hanna and Huang (2004) estimate that China's GDP contracted by over 5 percent in the second quarter of 2003 on a seasonally adjusted annualized basis, or a loss of around 0.5 percent of GDP for 2003 as a whole. Siu and Wong (2004) document similar demand side impacts on tourism and other services sectors in Hong Kong, leading to a fall in GDP in the second quarter of 2003 of 10.5 percent from the previous quarter, at a seasonally adjusted annualized rate. Leading the decline were a 43 percent drop in services exports (principally tourism) and a 7.9 percent drop in personal consumption by residents (both at quarter on quarter, seasonally adjusted annual rates). Exhibit 1 illustrates the pattern of a sharp GDP decline in the second quarter followed by a robust rebound in the third for not only Hong Kong but also Singapore and Taiwan (China). Calculating the counterfactual of how the economy would have grown without SARS is an uncertain and complicated matter. We note that Hong Kong real GDP was growing at a year on year pace of around 4.5 percent in the two quarters before SARS and in the two quarters after it. Making the simple minded assumption that the economy would have grown at 4.5 percent throughout the year without SARS leads to an estimated 1.1 percent loss in GDP for 2003 as a whole as a result of SARS. Using a more sophisticated econometric approach, Fan (2003) estimated a similar sized GDP loss for Singapore. Chou et al (2004) use a computable general equilibrium model to estimate a 0.6-0.7 percent GDP loss for Taiwan (China).

Exhibit 1



There is of course no one right answer about the size of the economic losses exacted by SARS. Much will depend on the underlying economic model that is applied, and the assumptions made about the conditions and policies that would have prevailed in a counterfactual scenario. The point here is merely to stress that a number of different analytical approaches all point to economic losses in the main SARS affected economies that are much larger than any that would have been suggested by the standard cost of illness approach: the estimated GDP losses in 2003 for the four economies discussed amount to on the order of $13 billion, despite there being only somewhat over 7000 possible cases and a little over 700 fatalities in the 4 economies combined.

The fact that the standard costs of illness were relatively unimportant in the SARS and Surat events should not be read to suggest that they are unimportant in general. Illness and death of course remain much the most important facts about infectious diseases. That, after all, is why people take protective action against such diseases in the first place. A potential human influenza pandemic is an example where both types of effects or costs would likely be important. This is a case where there could be both severe initial demand shocks arising from protective actions taken by individuals, as well as substantial costs of illness arising from morbidity and death on a large scale. Recent efforts to model the economic impacts of an influenza pandemic (for example Mckibbin and Sidorenko 2006, World Bank 2006a) therefore address both these sets of issues.

3. The Economic Epidemiology Approach – and Possible Embellishments

Work in economic epidemiology over the last decade or so may provide a useful theoretical model for analyzing events such as the Surat or SARS outbreaks, or a potential influenza pandemic.[4] Such a framework aims in principle to bring out the links between the epidemiology and dynamics of a disease, the purposive behavioral responses of people in reaction to the disease and the economic consequences that follow from these behavioral responses as well as from illness and death (the latter being the ground covered by the cost of illness model).

[4] For example Geoffard and Philipson (1996), Kremer (1996), Philipson (2000), and Gersovitz and Hammer (2001, 2003).

Insights from Economic Epidemiology

A key intuition in the economic epidemiology approach is that self-interested, forward looking individuals will adapt their behavior to take account of the prevalence of a disease and the threat it poses to them. They will typically change their behavior to better protect themselves as the prevalence of the disease increases, while also taking into account the costs of such protective actions. Geoffard and Philipson (1996) label this *prevalence-elastic behavior*. The prevalence of the disease will in turn also be affected by the changed behavior of individuals. Disease prevalence and protective action by individuals then both emerge as endogenous outcomes in a constrained dynamic optimization problem, the constraints being provided by the biology of the disease in question, the range and cost of protective actions that may be available for that disease and, importantly, the information available to individuals in making decisions.

Philipson (2000) and Gersovitz and Hammer (2001) model prevalence-elastic behavior in the context of a standard S-I-R epidemiological model (see for example, Anderson and May, 1991). We outline a highly simplified version to help fix ideas. Here the population N is comprised of the number who are susceptible to disease (S), infected and infectious (I) and recovered and immune (R).

(1) $N = S + I + R$

The proportions of these groups in the population are denoted in lower case letters, so that $s + i + r = 1$. The number of susceptibles in a given time period declines by the number who become newly infected, as shown in equation (2). The expression for new infections $\alpha S i$ assumes a homogenous population in which people have contact with each other at random and with equal probability. The probability that a susceptible person's next contact will be with an infected person is given by the aggregate infection (or prevalence) rate i. The expression S.i then gives the total number of susceptible people who meet an infected person, assuming every susceptible person has one contact. The adjustment factor α reflects both the inherent infectiousness of an infected person and the number of contacts per person per period.

(2) $dS/dt = -\alpha S i$.

In equation (3) the change in the number of infected people equals the number of new infections less the number of infected people who recover and become immune, given by δI, where δ is the rate at which an infected person recovers and R is the stock of recovered people.

(3) $dI/dt = \alpha S i - \delta I$.

(4) $dR/dt = \delta I$.

(5) $h = \alpha S i/S = \alpha i$.

In a purely epidemiological model the infection adjustment factor α and the recovery factor δ are some fixed parameters. In such a model the *hazard rate* h – the proportion of susceptible people who become newly infected in each period (Equation 5) – always increases as the prevalence rate i goes up.

In a choice-based model, on the other hand, α and δ become choice variables which the individual selects so as to maximize some utility function, subject to the constraints in equations (2)-(4). The recovery factor δ may be adjusted, for example, by choosing to spend more on medical care, while the infection adjustment factor α could be adjusted by reducing the number of contacts the individual has with other people. In such a model, the hazard rate may or may not rise, depending on whether and how much people push down the adjustment factor α in response to a rise in the prevalence rate i.

The protective choices open to individuals will differ according to the nature of the disease and other circumstances. Where a vaccine is available, the choice may be whether to take the vaccine or not. In the context of sexually transmitted diseases, the relevant choice variable becomes the number and type of sexual partners chosen ("assortative matching"), as well as condom use and other sexual practices. (Velasco-Hernandez and Hsieh 1994). Philipson (2000) summarizes evidence for significant prevalence-elasticity in the demand for condoms and choice of partners in relation to HIV-AIDS prevalence in the USA (as well as in the demand for vaccines in relation to prevalence of seasonal influenza, measles, mumps, rubella and MMR). Kremer (1996) explores a model where increased HIV-AIDS prevalence leads people with a low level of sexual activity to reduce their number of partners, but where people with high sexual activity may increase their number of partners (because of the high likelihood that one of their existing partners will already have infected them, a form of "rational fatalism"). Oster (2006) explores reasons for the apparent low prevalence elasticity of HIV-AIDS response in Africa.[5] Del Valle et al (2005) study the potential impact of behavioral change in a mathematic model of a smallpox outbreak. While most studies in this area have focused on infectious diseases where transmission is from person to person, Raut (2004) studies behavioral change in response to a vector-borne infectious disease, malaria.

The economic epidemiology approach should provide a natural framework for analyzing events like the Surat plague, SARS or a potential influenza pandemic in several ways. First, the essence of these events is a rapid and highly prevalence elastic response in the behavior of the public in response to the threat of a disease outbreak. People try to form a view of the likely characteristics of the disease, and then take actions to reduce the threat of becoming infected, for example by fleeing the area or by trying to reduce the number of contacts with other people in the area of the outbreak. An important priority for future research is to better understand the types and intensity of these prevalence elastic responses. In particular, how do such responses vary according to the transmission mechanism and virulence of the disease, the availability of information, the quality of the health system, the general level of economic development, and so on?

Second, the economic epidemiology approach draws attention to the costs of preventive actions, which in the case of Surat and SARS turned out to be the predominant

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[5] Oster (2006) looks at a problem for both traditional epidemiological and economic epidemiology models – the unexpectedly large scale of the HIV-AIDS epidemic in Africa and the apparent lack of prevalence elasticity there (compared to high elasticities of behavior change in developed countries, for example among gay men). Oster provides some evidence that low prevalence elasticity in Africa may be linked to low pre-existing life expectancy and low income levels. In other words, a person expecting to lead a short, impoverished life will be less inclined to change behavior in response to the threat of AIDS than a person expecting a long and wealthy one.

economic costs. Philipson (2000) indeed argues that where private behavior is significantly prevalence-elastic, the main welfare cost of a disease is likely to consist of the distorted behavior that the disease induces. For example, because there are no new polio infections in a developed economy like the United States does not mean that there is a zero cost of illness from this source. In fact polio exacts a significant ongoing cost in the form of the annual preventive vaccination effort that it induces.

Lastly, the economic epidemiology approach also points to the impact of private preventive behavior in driving disease dynamics. People's preventive behavior not only has costs but may also have potentially large benefits by breaking the transmission of the disease. Simulations by Del Valle et al (2005) suggest that even mild private behavioral changes could have a major impact in suppressing a smallpox outbreak. We do not know what impact the spontaneous efforts of people to reduce their daily contacts had in the surprisingly rapid disappearance of SARS. What role did private preventive behavior play in past human influenza pandemics and how might it affect the course of a future pandemic? These too are important areas for further research.

Uncertainty and Imperfect Information Considerations

However, while many features of the Surat and SARS episodes fit nicely within the general economic epidemiology framework, they also have some distinctive aspects related, in particular, to the high levels of uncertainty and very imperfect information available to individuals. Economic epidemiology analyses often assume that individuals decide on the optimal level of preventive action without making systematic errors about the objective situation they face, for example about whether an epidemic outbreak has occurred, about the transmission mechanism and infectiousness of the disease, the morbidity and mortality associated with infection and the overall disease prevalence rate in the population. In more technical terms individuals are assumed to have rational expectations: they do not have systematically biased subjective prior probabilities about the likelihood of relevant events. This is not in fact an unreasonable working assumption for infectious disease situations, when the costs of "getting it wrong" could be high – for example illness or death, on the one hand, or, on the other, the economic disruption and stress from excessive or unwarranted preventive actions. Individuals in disease situations should have strong incentives *not* to make systematic errors about the state of the world, or to try and quickly correct themselves when they do.[6]

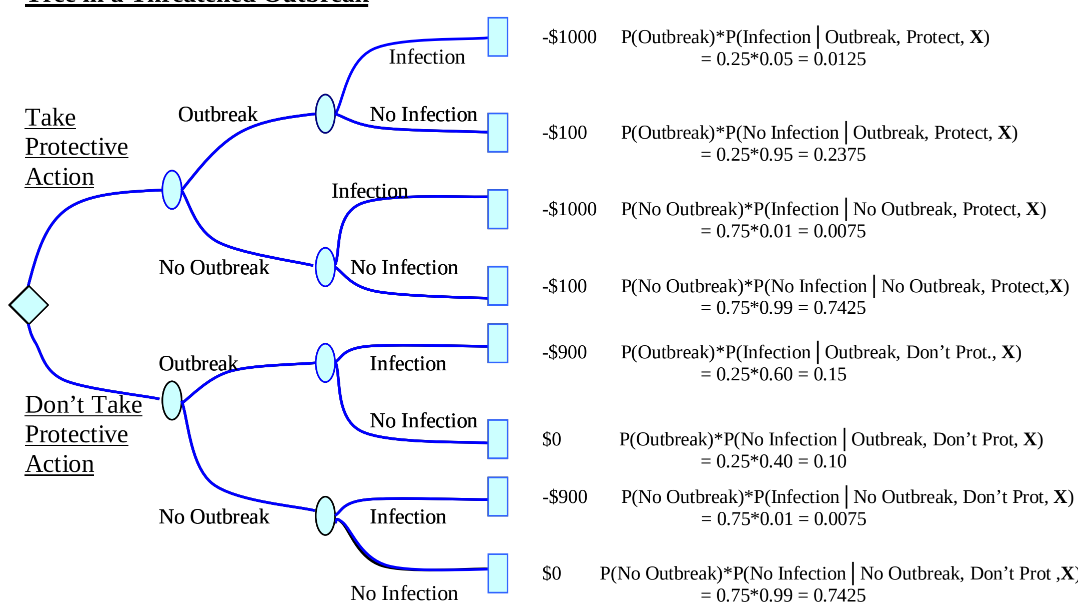
There is nevertheless suggestive contrasting evidence from the Surat and SARS events (see next section) that, under the prevailing conditions of poor information and stress, individuals may still arrive at significantly biased or systematically erroneous subjective assessments on critical factual issues, at least for a time, leading them to panic and take less than optimal decisions, resulting, in the aggregate, in an excessively high cost of private preventive action. The possibility of such biases is well documented by

[6] Caplan (2000) presents a model of "rational irrationality", where individuals may get some net utility from holding systematically erroneous beliefs, particularly when such beliefs are not too costly for one's own health and wealth, for example from believing that the theory of evolution is wrong or that one's nation is "the best in the world" (although such mistaken beliefs could turn out to be quite costly in the aggregate). However the demand for irrational personal beliefs should fall as the cost to one's self of being wrong increases.

broader research in psychology and behavioral economics; recent theoretical work on information cascades and herding behavior may also be relevant. These considerations suggest interesting directions in which to elaborate or embellish economic epidemiology models. At a practical policy level they lead to a strong focus on the importance of public information and risk communication strategies and on the problem of inducing agents (including governments) to reveal private information they may hold about the disease situation.

Before taking up these topics in more detail it may be useful to clarify a little further the decision problem facing an individual during an epidemic disease outbreak, highlighting the critical role played by the individual's subjective probabilities. Exhibit 2 shows a highly simplified decision tree for a (risk-neutral) individual who has to decide whether to take some protective action (for example whether to flee the city). To make this decision the individual needs to form a subjective probability about whether an epidemic outbreak has occurred. Say she thinks an outbreak has occurred with a 0.25 probability. Then she must assess the probability that she will get infected, which is a conditional probability: its value will depend on whether an outbreak has indeed occurred, on whether the individual has taken protective action and on other conditions (contained in the vector X), for example the quality of public health and medical services in the city, climatic conditions and, not least, the actions of other people.

Exhibit 2: Individual Decision Tree in a Threatened Outbreak



Let's say that in the event that an outbreak occurs when she has already taken protective action, the individual feels the probability of getting infected is a relatively low 0.05. If she were then to get infected, even after taking precautions, the cost of illness (plus the cost of the preventive action) would be, say, -$1000 in monetary terms. The expected value of the loss on this branch of her decision tree is then 0.25*0.05*-$1000 =

-$12.5. Adding up the values for the relevant branches (using the assumed probabilities shown in Exhibit 2), the expected loss from taking protective action is:

(-$1000*0.0125)+(-100*0.2375)+(-1000*0.0075)+(-100*0.7425) = -$118,

while the expected loss from inaction is:

(-$900*0.15)+($0*0.10)+(-$900*0.0075)+($0*0.7425) = -$141.75,

leading to a decision to take protective action. Obviously, this decision is quite sensitive to the subjective probabilities formed by the individual. If, for example, she assesses the probability of an outbreak as 0.2 or less, her decision switches to inaction. How people form subjective expectations under conditions of imperfect information and high stress then becomes crucial.

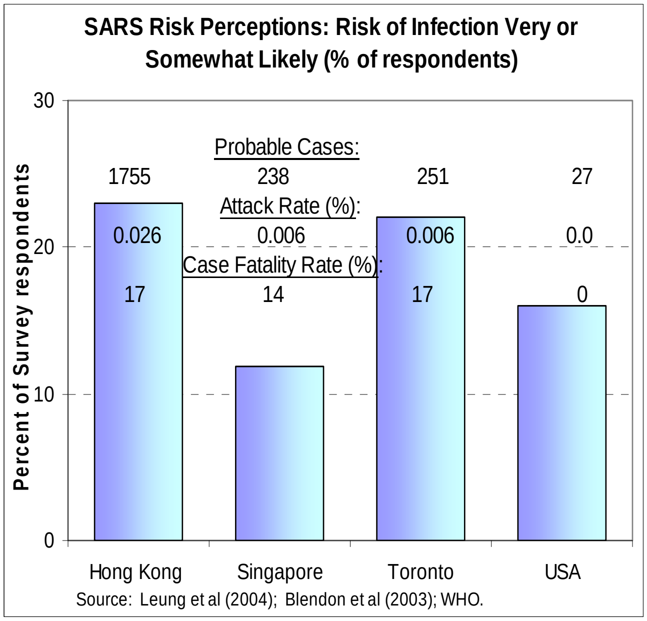
Insights from Behavioral Economics and Survey Evidence

High uncertainty and pervasive lack of credible information is a common feature in the early stages of many infectious disease outbreaks, especially in developing countries. People are thrown back on seeking information from rumors, word of mouth or sensationalized media reporting, as was seen in Surat or in Guangdong during SARS. Under these circumstances it would not be surprising to learn of substantial biases in people's subjective estimates of key probabilities, at least for a time. Research in behavioral economics over recent decades amply demonstrates the presence of such biases in probability judgments in many contexts.[7] Tversky and Kahneman (1974) note that, rather than undertake explicit probability calculations of the type illustrated in Exhibit 2, people generally form subjective probability judgments using "a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgmental operations." These heuristics are generally quite useful but "sometimes they lead to severe and systematic errors." The availability heuristic, for example, describes the tendency of people to assess the probability of an event according to the ease with which instances of the event can be brought to mind. There is then a tendency to seriously overweight events that are memorable, vivid in imagination or a source of fear or dread. People's estimates of the probability of having an automobile accident shoots up temporarily after they see an overturned car by the roadside. Similarly, people tend to greatly overestimate the risk posed by an uncommon but dreaded event like a nuclear accident (compared to the estimates of experts or the actual frequencies of such events), while they underestimate the risks from more common sources such as x-rays. (Slovic and Weber, 2002).

Another source of error is the representativeness heuristic: people tend to form conditional probability judgments about the likelihood of a hypothesis (given some evidence) by how well the evidence resembles the hypothesis. They tend, however, to ignore the prior or base rate probability of the hypothesis in question, or the likelihood of the evidence arising for reasons other than the hypothesis (thus breaching the requirements of Bayes Rule for calculating conditional probabilities). People may then vastly overestimate the probability that a disease outbreak has occurred (H, the

[7] See for example Tversky and Kahneman (1974), Rabin (1998), Mullainathan and Thaler (2000) and Camerer, Loewenstein and Rabin (2004) for surveys of this evidence. Frank (2004) looks at the contribution of behavioral economics to health economics.

Exhibit 3



hypothesis) given a certain number of disease deaths (E, the evidence) by confusing it with the probability of such deaths occurring given a disease outbreak (in probability notation by confusing P(H│E) with P(E│H)).

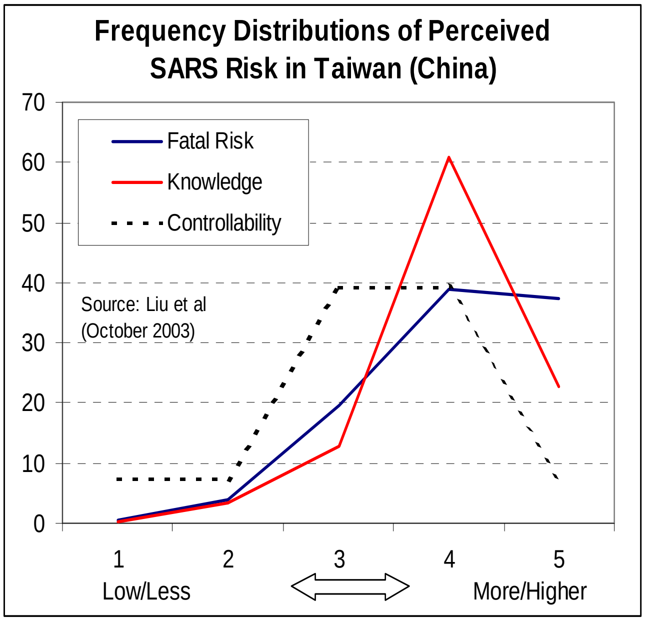
A number of surveys taken during the SARS outbreak provide direct evidence on people's subjective probability assessments. Leung et al (2004) report that nearly a quarter of respondents in Hong Kong thought that they personally were either very or somewhat likely to become infected with SARS (Exhibit 3), even though the *ex post* infection or attack rate in Hong Kong (probable cases reported to WHO relative to population) was only 26 per 100,000 population (0.0026 percent). In the United States some 16 percent of respondents thought that the event that they or their immediate family would get infected by SARS in the next twelve months was very or somewhat likely, despite an *ex post* attack rate not sensibly different from zero. (Blendon et al 2003).

Strictly speaking one cannot infer that these subjective probabilities were necessarily biased or too high by simply comparing them to *ex post* attack rates, because of the possibility that low *ex post* rates were themselves the endogenous result of preventive action taken by people, based on their subjective risk perceptions. The correct comparison might instead be to the theoretical counterfactual of what the ex post infection rate for SARS would have been had people not taken preventive actions, which is not an easy thing to calculate. The large gap between subjective risk perceptions and actual outcomes is suggestive nonetheless.

Survey evidence from Taiwan (China) throws light on some other aspects of risk perception, in particular the perceived risk of fatality in the event of infection and individuals' willingness to pay (WTP) to avoid infection. (Liu et al 2003). Exhibit 4 shows that 76 percent of respondents rated the likelihood of fatality after contracting SARS as 4 or 5 on a 5 point scale, which seems high compared to an actual case fatality rate in Taiwan (China) of 11 percent. This may provide clearer cut evidence of subjective overestimate of risk, since the actual case fatality rate after infection is unlikely to have been much affected by people's actions or risk perceptions. (The exhibit also shows that most respondents thought they had a high level of knowledge about the disease, as well a moderate level of control over the disease.)

Liu et al (2003) also asked people about their willingness to pay for a theoretical vaccine that eliminated the chance of infection given realistic odds of infection and mortality (3 or 5 per 100,000 per month for infection risk and 5 or 10 percent risk of mortality after infection). From these responses the study inferred a Value per Statistical

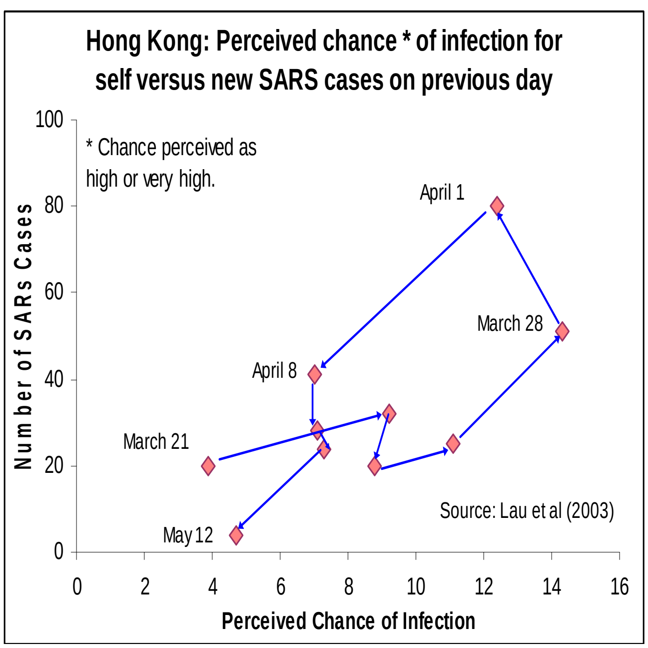
Exhibit 4



Life (VSL, interpreted as the marginal rate of substitution between income and mortality risk) in the range of $4-9 million per life, considerably higher than previous estimates of the VSL in Taiwan (China), which were in the range of $0.5-1.5 million. The authors suggest that the high estimates of VSL from SARS respondents may be attributable to the high degree of salience and concern about SARS, or to the possibility that respondents believed the risk they faced to be higher than the probabilities used in the survey (3 or 5 per 100,000 per month).

Finally, is it the case that, while people may make significant mistakes in forming subjective probabilities about disease events, they will tend to learn and improve these estimates over time? Rabin (1998) notes that while learning is a reasonable conjecture, it is not nearly as valid in many experimental situations as economists generally imagine. The amount of experimenting with new strategies or learning will depend on the opportunity costs of these activities, so that people could well stick with views and choices that turn out sub-optimal in the long run. (Mullainathan and Thaler 2000). However such persistence in error seems less likely in epidemic disease situations, when errors in judgment have significant short run costs. Lau et al (2003) appears to be unique in providing survey data (for Hong Kong) on how perceptions of SARS risk changed over time. Exhibit 5 maps the proportion of people who thought the chance of getting infected was high or very high against the number of SARS infections reported on the previous day between March and May 2003. The proportion of people concerned about a high risk of infection increased rapidly from around 4 to 14 percent of the population in late March, before coming back down to near 4 percent by mid May. These changes in perceptions were not random, tending to rise and fall in association with the number of new infections reported on the previous day. There is also a suggestion in the data that the impact

Exhibit 5



of new cases on perceptions tended to weaken with the cumulative number of cases, so that learning was not only short term (based on the previous day) but also based on cumulative experience of the outbreak as a whole. This evidence that perceptions in an infectious disease outbreak are sensitive to information suggests the possibility that government could help minimize unwarranted panic by providing the public with accurate and timely information about the true state of affairs.

Information Cascades and Herd Behavior?

Research on information cascades and herding behavior may also provide a useful framework for analyzing individual behavior during threatened infectious disease outbreaks.[8] The basic idea is that in situations of imperfect information individuals may rationally look at the *actions* of other individuals as a source of information about the state of the world. However this can sometimes lead to situations where most individuals jump to erroneous conclusions and socially sub-optimal decisions, for example to flee from the city even when the direct evidence available to them suggests otherwise.

A highly simplified version of such a story might be as follows. Individuals each receive different incomplete bits of private information (signals) about the state of the world, for example whether there has been an infectious disease outbreak in the city or not. These (risk neutral) individuals can also observe the actions taken by others, although not others' private signals. They decide between one of two actions, say to flee from the city or stay put, based on their private information and whatever they are able to surmise from the actions of others. Suppose individual A receives a signal that there has been a disease outbreak and flees. Individual B receives a signal that there is no outbreak, but observes that A has fled, presumably on the basis of a signal that there *is* an outbreak. Individual B does not know what to think and decides what to do by flipping a coin – which, as chance would have it, tells him to also flee. Individual C also receives a signal that there is no outbreak, but, observing that both A and B have fled, rationally decides that it is better to ignore his own signal and also flee. Thereafter there is an information cascade, with all subsequent individuals choosing to flee even if they all receive private signals that there is no outbreak.

Do information cascades provide a good model for panic behavior during infectious disease outbreaks (or, as has been claimed, for phenomena like financial panics, fads and manias)? Clearly, the model does generate predictions of the kind of sudden mass flight behavior experienced in some disease outbreaks. More interestingly, the theory also predicts the *fragility of herding behavior* with respect to small shocks, stressing the random element in the emergence of cascades. A slightly different sequence of signals could either precipitate or preclude a cascade, which provides a simple explanation for the observed fact that herding behavior occurs in some disease outbreaks but not in others. Since individuals in a cascade know that it is based on relatively little information, they are sensitive to the arrival of even small amounts of new information, for example through the arrival of better informed individuals or the release of new

[8] For example Banerjee (1992), Gale (1996), Bikhchandani, Hirshleifer and Welch (1998), Avery and Zemsky (1998), Bikhchandani and Sharma (2001), Chari and Kehoe (2003).

public information. This would explain why cascades tend to be short lived and also points to the policy role of public communications strategy.

Among the more significant criticisms of the model is its dependence on the assumption that people have only a discrete binary choice of actions (flee or stay put). If, however, individuals have more choices or can act along a continuum (for example by varying the number of contacts per day with other people), then their actions can communicate more information and the chances of a cascade are reduced. (Gale 1996). Information cascade models also do not admit of *prices*, which generally serve as powerful aggregators of information and whose presence could preclude information cascades. (Avery and Zemsky 1998). This criticism does not seem a major flaw in an infectious disease context, where there are generally no markets or prices reflecting information about the disease situation.[9] More recently Chari and Kehoe (2003) have argued that both these critiques of the information cascade/herding model (i.e. lack of continuous choices and lack of prices) can be rebutted when another assumption of the model is relaxed: the assumption that choices are made in some exogenously fixed sequence. When individuals are allowed to choose the timing of their actions ("endogenous timing") – a reasonable assumption in a disease context - then cascades and herding are found to occur even in models with continuous choices and prices. Overall it seems that information cascade models should provide a useful direction for further research into herding behavior during infectious disease outbreaks.

4. Information Strategies: Some Policy Considerations

In addition to the actions of private individuals, the assessments made by governments, their capabilities, actions and omissions also play a critical role in determining the economic and health impacts of infectious disease outbreaks. The preceding discussion in particular suggests a strong rationale for public information and risk communication strategies that could help people update mistaken risk perceptions more quickly, or, in a herding context, break erroneous information cascades more promptly, thereby reducing the scope for over-costly disease prevention strategies. We note two issues. First, governments, especially in developing countries, are themselves sometimes woefully ill-informed about disease situations. Strengthening weak disease surveillance systems is therefore an important priority in many countries. Second, if there are such benefits from providing the public with accurate information, why is it that

[9] It does however point to the possibility of creating artificial *information aggregation* or *prediction markets* as a deliberate policy instrument to help pool the many bits of information about the existing and likely future disease situation that may be scattered among thousands of individuals in society. An experimental Influenza Prediction Market is already functioning in the United States, with health care professionals trading contracts on the level of seasonal influenza activity in several US states in the coming year, with the price of the contract equaling the probability that a given influenza outcome will occur. An Avian Influenza Prediction Market also began trading in 2007. Experts in 40 countries trade contracts on, for example, whether the WHO will confirm a first human H5N1 case in North or South America by some given time, or whether the WHO will increase its phase of pandemic influenza alert by a given time. (On November 29, 2007 the contract on an increase in the WHO's alert level occurring by July 1, 2008 was trading at 7 cents on the dollar, i.e. a 7 percent probability.) Such prediction markets for political races are found to significantly outperform opinion polls. They could provide an important tool to strengthen infectious disease surveillance. (University of Iowa Health Prediction Markets 2007, Forsythe et al 1992).

governments sometimes try to *conceal* information about a disease outbreak from the public and from international bodies like the WHO? To achieve more transparent information strategies it is first necessary to understand the incentives for governments to conceal information about disease and to otherwise engage in strategic behavior that may result in less than optimal social outcomes at both national and global levels.

Educating the Educators

Especially in developing countries, governments themselves often function under conditions of highly imperfect information. Poor surveillance capabilities mean that officials are often uncertain about the occurrence or nature of an infectious disease outbreak. Cash and Narasimhan (2000) note that, in both the 1994 Surat plague outbreak and the 1991 cholera outbreak in Peru, lack of adequate testing facilities meant that the authorities were unable to collect reliable data quickly enough to provide an authoritative source of public information in the early days of the outbreak, allowing rumors and tendentious media reports to win the field. In these cases lack of adequate diagnostic facilities also led to the use of excessively broad case definitions and inflated case numbers, which, in turn, contributed to panic among the public and excessive trade restrictions by trading partners.

The problems of weak surveillance capacity can and should be addressed over time by devoting more effort to strengthening public health systems in this area, drawing not only on domestic resources but also on foreign financial and technical assistance. Concerns about avian influenza and a potential human influenza pandemic have indeed led to a significant increase in awareness about and development assistance aimed at strengthening animal and human health surveillance capacities in developing countries over the past 1-2 years. (See for example UNSIC 2006, UNSIC/World Bank 2006, World Bank 2006b). The revised International Health Regulations (IHR) adopted by the World Health Assembly in May 2005 also dramatically expand the scope of global public health surveillance, requiring governments to, among other things, promptly report "all events which may constitute a public health emergency of international concern" to the World Health Organization. (IHR 2005, Baker and Fidler 2006). The development of health prediction markets could also provide a powerful forward looking complement to traditional surveillance methods (as discussed in footnote 9 above).

Incentives in Public Risk Communications: Is Honesty the Best Policy?

Lack of public capability and resources are not the only source of poor information and lack of reporting about disease conditions. Under certain conditions governments can also have significant incentives to conceal or delay communicating information about disease conditions to the public, to other governments or to the World Health Organization. There were examples of such delays during the SARS outbreak in 2003.

There are several factors that shape the incentive for governments to delay releasing information on disease conditions. Especially in the early stages, there may be considerable uncertainty whether a disease outbreak will develop into a more serious epidemic. Sometimes a rash of illness from a known or unknown source will raise concerns but then just peters out and is forgotten. Given that the outbreak might simply fizzle out of its own accord, there is an incentive for the authorities to "wait and see". This incentive will be particularly strong when a premature announcement could lead to severe economic losses because of panic, excessive preventive actions by the public (for example flight from affected areas), declines in foreign tourism and severe and often unwarranted trade restrictions on the country's exports imposed by other governments. Cash and Narasimhan (2000) observe that the trade and travel restrictions imposed on India in 1994 went far beyond the precautions for plague recommended in WHO regulations and occurred despite an explicit WHO request that such restrictions not be imposed on India. Later, both the WHO and CDC concluded that the actions against India taken by other countries had been both excessive and unnecessary.[10] There could also be large political costs for a government that is seen to "cry wolf" and cause losses "unnecessarily". In 1976 an outbreak of swine flu in the US raised concerns about a potential human pandemic influenza. Instead of downplaying or concealing the threat the authorities "did the right thing" and launched an aggressive public communication and preventive immunization program to counter it. Unfortunately this effort turned into a political disaster for the administration when a pandemic failed to occur and, instead, the vaccination program itself led to medical complications, some deaths and a "litigation nightmare". (Kolata 1999).

Alongside these putative benefits from delaying risk communications, there are also, of course, major potential costs. An obvious one is the increase in epidemiological risk from delays in launching public health measures and in calling on international partners for technical and financial help to counter the outbreak. This risk may be profound for new diseases such as SARS or a new pandemic influenza virus. In a potential human influenza pandemic, modeling suggests it may be possible to contain the pandemic strain at its point of origin using a rapid deployment of antiviral prophylaxis as well as social distancing measures, as long as the basic reproductive number, R_0, is not above 1.8. (Ferguson *et al* 2005). However, success in such a strategy would depend on ready access to local and international stockpiles of relevant drugs, rapid case detection and delivery of treatment, and the cooperation of the population in the containment strategy, most of which presume extremely rapid sharing of information with international partners and a timely and credible public risk communication plan.

Second, governments are sometimes over-confident about their ability to suppress or delay communication about a possible disease outbreak. The growing availability of modern mass communications technologies like cell phones and internet access even in

[10] Why do governments in non-outbreak countries appear to have such strong incentives to impose excessive trade and travel restrictions on potential outbreak countries? One simple hypothesis is that they are merely responding to exaggerated perceptions of risk among their own publics (no doubt fuelled by lurid media accounts of the disease). Governments may then see large political benefits and few costs from pandering to such fears by imposing unwarranted trade restrictions on the affected country. The fact that the purely economic welfare cost of trade restrictions will generally exceed their benefit may not carry much weight in political economy terms: economic costs will generally be spread over the mass of consumers and may amount to only a few cents per capita, so that there is unlikely to be any organized political opposition to the restrictions, while domestic producers who compete with the imported products are likely to be highly organized and vocal in their support for restrictions. This is clearly an area that would repay further study.

developing countries means that information or speculation about an outbreak is likely to quickly spread within and outside the affected country through all sorts of unofficial channels – person to person communications, NGOs, businesses, media channels etc. - as occurred during SARS. Among the key points that are likely to be communicated through these informal channels is precisely the observation that the government may be trying to suppress information about the outbreak. This may then encourage a loss of trust in the government, even more reliance on rumor and speculation and even more excessive protective actions by the public than would have been the case if the government had "bitten the bullet" and reported transparently on whatever information it had in the first place. The affected country may also lose reputation and credibility as a trustworthy international partner, thereby strengthening the rationale for other countries to use trade restrictions against it. Recognizing the growing importance of these unofficial sources, the IHR 2005 permit the WHO to collect and use information from multiple non-governmental sources in conducting its global surveillance, rather than, as previously, only from state sources.

In a recent study Laxminarayan and Malani (2006) evaluate many of these costs and benefits in a game-theoretic analysis of the disease surveillance and reporting decisions that face governments in affected countries. In this model governments first decide how much to invest in their disease surveillance systems, and then on whether to report the findings of the surveillance system as to whether there has been a disease outbreak. Governments make these decisions on the basis of the probabilities they attach to several key events that help determine the payoffs to the game: whether or not there will be a disease outbreak; whether the disease surveillance system will correctly signal the occurrence (or non-occurrence) of an outbreak; and whether the outbreak will escalate into a full-blown epidemic. If a country decides to report an outbreak, it receives medical assistance from the WHO (which reduces the probability of an epidemic), but it also suffers *ex post* trade sanctions from the rest of the world. Using backward induction to solve the government's reporting problem leads to the conclusion that the government will be more likely to report an outbreak the smaller are *ex post* sanctions and the greater is the medical assistance from the WHO. It is also more likely to report the greater is the chance of an outbreak escalating into an epidemic, the greater the number of lives lost in an epidemic and the more the government values those lives. This suggests concealment may be more likely for a new disease whose virulence is initially not well known, like SARS, then for a better known and potentially very high mortality disease such as pandemic human influenza.

What policy options might WHO deploy to induce greater disease reporting? Increased medical assistance would work in the right direction, but would of course be limited by the budget available to WHO. Another theoretical possibility is giving WHO (or some other relevant international agency) the power to impose some form of punitive sanctions on a country that experiences an epidemic without having reported the preceding outbreak. This is unlikely to be very effective, however, because the country will already be suffering *ex post* sanctions from the rest of the world, and one more will make little difference. A more promising policy direction might instead be to curb excessive *ex post* trade sanctions by other countries, which, as noted, tend to discourage reporting by the affected country. Consideration could be given to strengthening the powers of the WHO (probably in cooperation with the WTO) to discourage or prohibit states from applying extreme health-related *ex post* trade sanctions beyond those measures approved by the WHO in a given case.

Laxminarayan and Malani (2006) also analyze the important real world case of *preemptive sanctions*: countries in the rest of the world (or their citizens) often impose sanctions *before* any formal report from the country, based on their beliefs about the probability of an outbreak having occurred. (Indeed, we can add, a country's own citizens often impose their own preemptive sanctions, through the sorts of private preventive actions discussed above.) Such beliefs are likely to be well correlated with the volume of information about possible outbreaks flowing out through informal or non-official channels. In contrast to *ex post* sanctions, the analysis of this case suggests that preemptive sanctions are likely to *increase* disease surveillance and reporting by outbreak countries. Because a country might be sanctioned even if it does not report an outbreak, the incremental cost of reporting falls.

Some interesting policy implications flow from this analysis. For example, policy measures that increase the flow of information about countries (for example widespread cell phone use, or the new powers of the WHO to collect and use non-official information) should also increase the incentives to report. The existence of independent health prediction markets (described in footnote 9 above) could also have this effect. Under these conditions countries that in fact have a lower than average risk of an outbreak will have an incentive to communicate this fact to the rest of the world. This would provide the WHO with another policy instrument, the ability to audit and verify the quality and transparency of a country's surveillance system. As lower risk countries are vetted by the WHO, the rest of the world will tend to increase its estimate of the probability of an outbreak in the higher risk un-vetted countries that remain, increasing the probability of pre-emptive sanctions on these countries. This will then increase the incentives for the less risk-prone among these remaining countries to also get audited by the WHO – and so on, a virtuous snowballing or so-called "reverse lemons" effect.

Given that in the modern mass communications universe there is little hope of any but the most rigorously isolated country being able to prevent a flow of (possibly inaccurate) non-official information about the disease situation, simple openness and honesty may be a better approach. Straightforward reporting about what the government and public health specialists know or do not know would help squeeze out the space for unfounded rumor and would provide the population with tools to protect themselves in ways that minimize the chance of panic and excessive costs of prevention.

Singapore's pro-active and transparent information strategy during the SARS crisis can provide useful pointers here. The Ministry of Health issued its first SARS update on March 13, the day after WHO issued its first global alert on SARS, and thereafter issued daily or twice daily updates till the end of May. These updates provided a stream of the best objective information available at the time on the nature of the disease, symptoms, transmission mechanism, numbers of infections, fatalities, chances of recovery and preventive health care information. (Singapore Ministry of Health 2003). The health ministry updates were part of an extensive information campaign waged using websites, telephone hotlines, TV, radio, newspaper ads and posters, with political support from the highest level of the government, under the slogan "Fighting SARS Together". (Government of Singapore 2003).

Did it work? We are not aware of any systematic studies comparing information strategies in the SARS infected countries and their potential effects on public risk perceptions, on public behavior and on ultimate economic and epidemiological outcomes, which would in any case be a complex statistical undertaking, given the many and subtle mutual interdependencies at work. Exhibit 2 above showed that the proportion of people in Singapore who thought it very or somewhat likely that they would get infected was less than half that in Hong Kong. However that may only reflect the fact that the attack rate of the disease was also much lower in Singapore than in Hong Kong. More research is clearly needed.

5. Final Remarks

This paper looks at some lessons about the economic impacts of infectious diseases suggested by the SARS epidemic of 2003, the Surat plague outbreak of 1994 and other similar events. The distinctive feature of these episodes is that although they ultimately result in relatively little illness and death, they entail large economic costs which are primarily the result of excessive preventive behavior by individuals and (on occasion) governments. The paper suggests that recent work in economic epidemiology may provide a natural framework for analyzing SARS/Surat type events, where preventive costs predominate, diseases like HIV-AIDS, where the costs of illness and death predominate, as well as diseases like pandemic influenza, where both types of cost could be very high. A particularly valuable feature of this approach is the central attention it gives to the behavioral choices made by individuals as a key variable in the epidemiology and dynamics of infectious disease. Such a focus also naturally draws attention to the subjective judgments of probability on which individuals base their decisions, and to the psychological, informational and social influences that shape such judgments. The possibility of economically costly biases and errors in individuals' subjective judgments about disease suggest a potentially important role for public information and risk communication strategies. But account also needs to be taken of the incentives for governments to be transparent (or otherwise) in risk communications. The growth of mass communications technologies in non-official hands (cell phones, internet etc) appears to increase incentives for official honesty.

While the paper has pointed to recent work in different areas of economics that helps provide a more coherent conceptual framework for analyzing the economic impacts of infectious diseases, it also makes apparent the need for much more detailed and disease-specific research on the key relationships between disease biology, epidemiology and behavioral choice. An important research priority is to gain a better understanding of the types and intensity of prevalence elastic responses for different diseases, and of how they vary according to the transmission mechanism, virulence and other biological characteristics of the disease, the availability of information about the disease, the quality of medical and public health resources that are available, the general level of economic development, and so on. We need in particular to better understand how people gather information, form their perceptions of risk and make decisions in the high stress environment of an infectious disease outbreak. Public opinion surveys taken during SARS provide tantalizing glimpses of public perceptions at these times, but such information needs to be gathered much more extensively and with more attention to survey design. The WHO could play an important role by formulating and making available appropriate standard survey instruments that local universities or public health research institutions could use to quickly begin surveys when a disease outbreak occurs in some part of the world. Such information could also help governments design more effective information strategies to address the most significant information gaps or confusions among the public. More research is also needed on the feedback from private behavioral changes to disease epidemiology. Just how effective were private behavior changes in helping curb SARS, for example? Could the same effects have been achieved by less extreme or different behavior changes? Information of this kind could help public health authorities design better disease surveillance and control strategies which draw upon the active participation of the public while reducing inadvertent or excessive side-effects on the economy. Collaboration across diverse scientific disciplines such as disease biology, epidemiology, economics and psychology is likely to prove especially fruitful in this research program.

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