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Economic Aspects of Agricultural and Food Biosecurity in the United States

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Abstract

Concerns about biosecurity in the food system raise a variety of issues about how the system is presently organized, why it might be vulnerable, what one could reasonably do to better secure it, and the costs of doing so. After presenting some facts about US agriculture and food, this paper considers three economic aspects of the general problem. One is the global problem, or the way biosecurity measures can affect how countries relate to each other and the global consequences that result. Another is how to best manage the immediate aftermath of a realized threat in order to minimize damage. The third is how to seek to prevent realization of the threat. Some policy alternatives are also presented.

Keywords: agro-terrorism, animal disease, biosecurity, epidemic, food system policy.

Economic Aspects of Agricultural and Food Biosecurity

1. Introduction

The economic dimensions of agricultural and food biosecurity cannot be ignored and go far beyond loss estimation. According to the online dictionary Encarta[®], Biosecurity is “the protection of the economy, environment, and health of living things from diseases, pests, and bioterrorism.” Robbins (1935) defined economics as the inquiry into “choices made by individuals and societies concerning alternative uses of scarce resources employed to satisfy unlimited wants.” Efforts to provide security, be they in supporting a biological immune system, a state’s standing army, or the perimeters of one’s business operations, inevitably consume scarce resources.

To those with malevolent intent, the food system is a plum prize. It is biological, offering opportunities to trick the target into growing the noxious agent. Food is consumed, providing a direct delivery mechanism. Food has cultural resonance in that it helps to define a society and is usually consumed in the seeming security of one’s own home. A significant failure in the food system can undermine a population’s confidence in its government and institutions in ways few others can. In addition, the food system is in some ways particularly vulnerable to natural breakdown and deliberate attack. Others have elaborated on this (see Kimball, 2006), and I will mention vulnerabilities only when relevant to other discussions.

In at least one relevant sense, Robbins’s definition is insufficiently articulate and this is especially so when the matter is biosecurity. Biosecurity is provided at many levels, and decisions are made with diverse objectives in mind. Centralized decision-making on biosecurity in agriculture, a very decentralized sector, is not possible. Any endeavor to understand and encourage appropriate biosecurity choices must address these divergent incentives. Consider a government with the welfare of all consumers in mind, and also a producer who wishes to market products people want to consume. The government would generally find it best to leave the market alone. This is because consumers are best positioned to choose what they want, and for how much, while producers are best positioned to decide on what to make, and for how much. Sometimes, though, consumers may not know what they are getting because unwholesome food may not be readily apparent to consumers at the point of trade. Indeed,

producers may not know the true attributes of their produce. The government may have to act by monitoring quality or mandating actions.

Furthermore, the objectives of different governments need not be consistent when it comes to biosecurity. Regions differ in regard to endemic diseases and pests. Consumers differ in strength of demand for food quality and safety. Societies differ in perceived vulnerabilities. In addition, exporting countries may view certain importer biosecurity requirements as trade protectionism. The objectives of different producers may also differ. Activities on a farm have biosecurity consequences for other farms. Infectious diseases spread spatially from farms where misfortune and/or lapses in defense have allowed entry. A farm may have insufficient incentive to incur a cost it bears in full in order to provide a benefit it shares only in part. Thus, the government may seek to, as best it can, promote biosecurity.

And finally there is the terrorist. The rationale for such activities may be to create a sense of insecurity to the extent that the targeted institution cannot function as intended. Reconciling biosecurity incentives between some different parties may be feasible because appropriate measures can guide one party to take account of the consequences of its actions for others. In the case of terrorism, any reconciliation is unlikely. Resolution to thwart the terrorist does not, however, obviate the need to minimize the expected cost of damage.

The remainder of this paper has five main parts. The first provides some facts about US food production, and about what economics can say concerning losses from biosecurity problems. The second deals with reassessing how open the country is to the outside. Any such reassessment inevitably exposes for debate and legislation contentious issues concerning trade, immigration, and personal freedom. In the third main part, aspects of response strategies in the event of a threat realization are considered. The next section steps back to ask what could be done to prevent the crisis. The final part presents some policy suggestions.

2. Some Facts, and a Disclaimer

While on-farm agriculture, viewed narrowly, accounted for about 1% of US GDP in 2005, the share of US GDP spent on food was 8.2% in that year. Agriculture in the EU-25 accounts for about 1.6% of GDP while the share of GDP spent on food and non-alcoholic beverages is about

13%.¹ This section discusses production, trade, and what economics can say about various costs arising due to biosecurity endeavors and biosecurity failures.

2.1 Production and Trade

Table 1 lists market receipts for the main US farm commodities, while Table 2 lists revenues from some of the main exports. The United States, being a large geographic area, is more diverse in its agricultural outputs than most countries. Farm-level receipts when averaged over the US population amount to about \$790/person. Table 1 shows that crops and livestock account for approximately equal revenue shares, but livestock enterprises occupy the first three rankings and bovines account for 31.8% of receipts.

The commodities listed in these tables pose some apparent biosecurity apprehensions. In recent years, costly commingling problems have occurred with genetically modified corn and rice. Corn, soybeans, and wheat enter a large variety of products so that product recalls would be expensive. A successful attack on an exported commodity may result in foreclosed world markets, causing large losses. An attack on an imported commodity when being produced can circumvent internal safeguards on production activities. For orchard crops, an attack would eliminate capital assets, involve orchard pull-up costs, and disrupt markets for several years. These crops tend to be geographically concentrated, so the spread of a disease may more readily occur. Threats to Napa Valley wine might readily catch headline attention and could have repercussions for tourism.

On the whole, animals seem to be more vulnerable targets, if only because the produce affected move, are more valuable, and can be more difficult to clear of disease. Destroying a large number of animals is emotionally stressful for all concerned. In addition, indoor production in large scale allows for rapid spread of an infectious agent within a given herd.

2.2. Estimating Losses

A proper accounting for economic losses to an economy from endemic animal and crop diseases is difficult because one has, for example, to include prevention costs. Estimates in Harvey (2001) suggest product-level costs of lost production of 14% for hogs, 11% for milk, 9% for beef, and 8% for sheep if foot and mouth disease (FMD) became endemic in the United

¹ GDP, product sales, and other commonly used measures of economic contributions are not good measures of true contribution. Water and air are essential for life but make small contributions to the GDP measure. Data for better measures are generally too costly to obtain.

Kingdom. The cost to the United States of endemic animal-disease-related losses has been estimated at \$17.5 billion per year (National Academies, 2005), about 18.2% of the \$96 billion estimated value of livestock in 2005. Losses in less developed countries are likely much larger as a percentage of lost animal production. These estimates should be regarded as highly speculative because the reference point of production absent the disease is not well-defined. For example, productivity compromises can be made when breeding animals and plants in order to protect against diseases.

Possible losses due to an inadvertent or deliberate introduction of an animal or crop disease are even more difficult to measure. Market disruptions, including whether the disruptions are temporary, are an issue. There will also be transfers in economic welfare because consumers will demand other foods instead, bidding prices up. In addition, such events are so infrequent and so distinctive that the capacity of the system to cope can never be known with high confidence. Indefinite loss of access to international markets is likely to be a more significant issue. Welfare losses to an exporting country can be large because market access can be denied long after the technical problem at issue should have been considered resolved. The destruction of valuable genetic stock is another issue, as is the possibility of human deaths. Human mortality carries with it distinctive loss evaluation problems (Ashenfelter, 2006). Health impairments, lost days at work, and stress-related accidents are other concerns that economists could place losses on if the extent of such occurrences were provided to them.

There is also the issue of carcass disposal if control involves slaughter. With FMD, Jin, Huang, and McCarl (2005) compare a strategy of vaccination for later slaughter with one of immediate slaughter and immediate disposal. The vaccinate-and-hold approach may be more efficient when it is costly to dispose at short notice. In any case, any slaughter program could pose daunting logistical problems. Iowa does not intend to burn carcasses because of air quality concerns while burial poses water quality problems. Preventive costs cannot be ignored either. Identity preservation as a preventive measure can be very costly. Identity preservation also illustrates a complication in loss estimation. It protects against accidental and deliberate commingling and allows for information-related market premia in differentiated product markets. So attribution of costs across different motives for use would be challenging.

A further problem is that little is known about country vulnerabilities to a biosecurity failure. This is so for failures that are natural in origin, and particularly so for any terrorism-related

failure. In addition, if terrorist goals are to create and manipulate uncertainties, then ascribing probabilities to different events is an almost insurmountably difficult task. So economists can make a stab at quantifying losses when the physical realities (extent and location of outbreak, human effects, etc.) of an event are presented to them. But they also need probability assessments of different physical realities if they are to assist in preventing and preparing for a failure. To work best, economists need to interact with epidemiologists so that the economic consequences of strategies engaged in at the field level are compared before these strategies are taken.

Table 3 presents and comments on some of the many losses that can arise. The set of subject parties is not intended to be complete. Column 2 denotes ex ante, or preventive, costs as well as ex post costs. A subjective assessment of how capable economic tools are at measuring the loss is also provided. The word “maybe” often refers to unresolved issues in the use of such tools as survey instruments and economic experiments. In general, the estimation procedure takes time but back-of-the-envelope assessments can sometimes be provided with some confidence. An important item when reading the table is that the costs of preventing and dealing with natural pathogen attacks are unavoidable given the state of the world. But the additional costs of dealing with intentional attack are not a complete loss to society. Some of the extra resources interact beneficially with resources allocated to addressing natural pathogen attack. For example, additional veterinary resources put in place to diagnose a deliberate attack from an unspecified agent are also available to diagnose a natural outbreak.

Assessing vulnerabilities and measuring losses allow for informed choices among practically grounded approaches to remedies. Among these decisions, biosecurity problems often concern the country’s boundaries so that many decisions have international dimensions.

3. Global Problems

In this section I consider two themes regarding these international dimensions. One is that biosecurity is often what is referred to as a public good. At the country level of analysis, this means that the good is best provided at the global level. The other theme is that of trade, which can be adversely affected by biosecurity measures.

3.1. Public Goods

A public good is one that can be used by more than one consumer without unduly

compromising its utility to other consumers. A food item is not a public good whereas a road is. Many goods that provide security are public in nature; a police force seeks to secure all citizens and property in a town. At the international level, biosecurity may be considered to be a public good. If a communicable diseases problem is eliminated in some country, then all other countries gain in this globalized age. To some extent, security from terrorism is also an international public good, as many terrorists target multiple countries.

Through some of its units, the United Nations seeks to control infectious animal diseases at the transnational level. Separately, the World Organization for Animal Health (or OIE) is dedicated to addressing public goods aspects of global animal disease problems. For many low- and middle-income countries, animal agriculture is comparatively important; very limited veterinary resources are available, while national governance structures are often weak and unstable. OIE efforts include information transfer, coordination activities, and endeavors to provide continuity in animal disease management efforts. These and related infrastructure may assume greater importance in the years to come if regulations and labor costs cause animal production to exit developed countries.

Is it wasteful for several transnational entities to address infectious agricultural disease problems in less developed countries? Probably not. These entities often have different goals and approaches. Developed and developing countries differ in ways that matter for the spread of infectious disease. Apart from contrasting healthcare infrastructure and production practices, the climate tends to be more temperate and fewer wildlife reservoirs remain in developed countries. Diseases that concern developed countries are not necessarily those most damaging to developing countries. A single entity trying to meet all the goals of recipient and donor countries might devote too much energy to reconciling conflicting objectives.

3.2. International Trade

Food export markets are important for many countries, including some that are developed and heavily urban. Huang (2000), Thompson *et al.* (2002), Blake, Sinclair, and Sugiyarto (2003), Breeze (2004), and Blayney, Dyck, and Harvey (2006) provide perspectives on how FMD has affected production in Taiwan and the United Kingdom over the past decade. Why is such emphasis placed on maintaining access to international markets? The theory of comparative advantage is the idea that two parties (be they individuals or countries) can benefit from trading goods even if one party has an absolute advantage in producing both goods. Trade allows for

gains from specialization in our diverse capabilities, and comparative advantage determines the direction of trade. Beyond that, there is a belief that trade (and migration) are associated with technology transfer.

The theory comes, however, with important qualifications. Among these is the absence of what are known as negative externalities. These are costs that someone imposes on someone else, i.e., people do not bear all consequences of their actions. Infectious disease and incomplete information on product safety are classic illustrations of a negative externality, and so there can be grounds for placing trade restrictions. There can also be grounds for better preparing countries for some adverse consequences of increasing openness, and many are concerned that this is not happening (Kimball, 2006). While a country as a whole may gain from trade, some interest groups may lose. The possibility of trade restrictions due to concerns about infectious animal and plant disease, therefore, provides groups with an opportunity to renegotiate a market environment. Although the politics are often appealing, the economic consequences of widespread renegotiations of this sort would likely be very negative in the long run.

In summary, endeavors to address vulnerabilities at the border provide strong international dimensions to biosecurity problems. Possible responses include tackling problems at their source, trying to restrict movements of goods and people, or monitoring borders for suspicious traffic. It is the preponderant view among economists that potential losses would have to be very large before tight restrictions on the movements of goods and people would be the most appropriate action.

4. Responses

Rapid mobilization of resources during a crisis can be challenging for a free society. Often, resources have to be coaxed free while urgent decisions must be made about trade-offs between individual rights and the public good. In the case of animal and crop diseases outbreaks, the sacrifices to be made may jeopardize a business's capacity to survive. In addition, the growing share of non-farmers in a community will be asked to forbear for a sector that has developed image problems of various hues. This section deals with some issues on response in crisis that are distinctive to rural locations and agricultural/food markets.

4.1. Leadership

No matter how much control a government attempts to assume during a crisis, people often

quietly ignore edicts whenever a government does not have the information and resources to compel (O'Toole, Mair, and Inglesby, 2002). To some extent, trust and sustained cooperation originate in the incentives people feel they countenance. Individuals will be best disposed to behave as desired if they believe leaders have few incentives to mislead and if they know others face comparable sacrifices. Leaders need to engender and convey the spirit of common sacrifice.

But leadership goes far beyond that. It is sometimes the case that (a) two interacting individuals act such that both are happy with their actions given the behavior of the other party, but (b) neither should be happy with the overall outcome. For example, everyone might agree that travel be curtailed during an FMD outbreak, but everyone also hopes that others will curtail. Leadership often involves cajoling people to see that what is in the public interest is also in one's private best interest, i.e., leadership has a coordination function. Rural areas, often with more clearly defined civic leadership structures, can be well-suited in some ways to meeting the public interest when great needs arise.

Timeliness is another facet of leadership's coordinating role, as what are the right decisions may depend on promptness in decision-taking. Almost inevitably, a significant biosecurity failure will involve a novel context. Cold-eyed attention is warranted when evaluating an institution's structural capacity for flexibility in approaching problems and decisiveness in taking actions. On a similar theme, while continuity between preparation and response is necessary, one wonders whether 8-to-5 urban civil servants are appropriate leaders for crisis management in rural areas. Institutional flexibility and incentives mechanisms in one's employment history may affect the development of human capital traits needed when leadership roles must be assumed in crisis.

4.2. Communications and Demographic Differences

Much has been written about communication in security crises, as cited in Sorensen (2004) and elsewhere. Issues somewhat distinct to agriculture do merit attention, however. Modes of communication differ across developed world rural and urban areas, more so in the developing world. This is not always to the disadvantage of rural areas. Rural communities tend to be more stable and homogeneous, so that contact is more likely. Another issue is the demographic trend against farm employment in rural areas, especially when within commuting distance of a large urban area. Agriculture accounted for 12.4% of jobs in non-metro statistical areas of the United States in 1976 but only 6.2% in 2004.

Table 4 shows that ownership structures are increasingly concentrated.² Poultry and feedlot beef production have long been large-scale, while this is now true of hog and dairy production. Hog operations with over 10,000 animals now account for half of US output but less than 1% of all producers. Of 938 million farmland acres in 2002, 353 million were rented or leased. In Iowa, 20% of farmland is owned by someone not living in the state while 46% of Iowa farmland was operator-owned in 2002 (Duffy *et al.*, 2003). Isolation is a primary reason rural America has had methamphetamine production problems in recent years. In addition, environmental problems are changing how farming and non-farming neighbors view each other and will perhaps decrease tolerance for inconveniences that will arise in attempts to control a disease outbreak.

4.3. Information Systems and Animal Identification

Response to infectious disease is a classic case of a public good, and a role for government cannot be disputed. Recent disruptive animal disease events have convinced many in developed world animal agriculture industries of the pressing need for better animal tracing capacity. This capacity should be as far-reaching as is practicable and should certainly include premises registration. EU regulation 820/97 requires identification and tracing capabilities for EU bovines and bovine products. EU countries share movement information, and many EU countries have developed GIS systems to use this information (Kroschewski *et al.*, 2006).

The United States has responded by seeking to institute a voluntary National Animal Identification System (NAIS) involving premises registration, animal identification, and tracing capacity. Whether the NAIS that emerges is well-coordinated must be a concern. Diverse databases may require costly human intervention during a crisis. By contrast with the EU, where commodity tracing has been mandated, the US has less leverage with animal producers. This is because the US animal agriculture sector has received very little in the way of direct subsidies that can be made conditional on farm-level actions. In addition, producers tend to be less accepting of government intrusion. Even so, some producer organizations have been very supportive of premises registration. Private sector identification systems are also expanding because of increasing demand for product and source verification and because of growth in contract agriculture. The US sheep sector already has a template identification system in place.

² Rushton and Upton (2006) provide other details on rural demography and animal sector structure as they relate to biological emergencies.

This arose from mandatory federal regulations to identify breeding animals for the National Scrapie Eradication Program, which commenced in 2001.

4.4. Preparation for Response

Perhaps the most important issue concerning preparedness for an animal-related biosecurity failure is where veterinary personnel would come from. The US veterinary medicine profession is increasingly non-agricultural, with fewer than 10,000 private practitioners significantly involved in animal agriculture (National Academies, 2005). Animal sector intensification and the declining real dollar value of animals have been responsible for reduced farm demand for veterinary services. These trends are likely to continue, although perhaps modified by the rise in organic and other alternative farming models. Veterinary services at larger farms increasingly deal with herd health. Industrial-format production simplifies preparation for response because identifying and processing the majority of animals will be easier. Nonetheless, the declining stock of veterinary professionals serving agriculture should be a concern. As for the larger picture, transparency and accountability can motivate those involved in making contingency plans and those who appoint them. Open discourse, a free press, democracy, and an educated electorate play a role in setting incentives for preparation.

5. Prevention

Prevention involves making resource allocation choices about low probability risks that may materialize in the indefinite future. We are not particularly good at making such decisions, tending to overemphasize some risks, underemphasize other risks, and place too much weight on the recent past (Thaler, 1992). These failings are systematic, applying just as well in the collective (i.e., for government decisions) as in the individual. Leaving aside concerns about deciding what to do, what follows comments on four aspects of implementing prevention strategies of particular relevance to agricultural biosecurity.

5.1. Communication and Education

Entry of an exotic infectious disease is most likely at the weakest link, spreading from there. If a costly action can be taken by each participant in the industry to reduce entry risk, participants can follow one of two strategies. They can fail to act out of the belief that they have little control over whether they are affected. Or they can believe that others are likely to do their parts and view themselves as the weak link. Then each participant has strong incentives to act. It all

depends on what participants think others are doing and thus on the information they have available about the behavior of others. Communication is key, and this can occur through animal industry groups or through government programs. Some US producer groups (e.g., poultry) have been more active in biosecurity outreach than others, perhaps because of perceived risk. Given their educational outreach mission, land grant universities are appropriate places to look for organized outreach. A cursory scan of the Internet, together with informal discussions, suggests that the extent to which veterinary medicine extension personnel in the United States are coordinating in providing biosecurity materials could be improved upon. Two questions are, is there a centralized biosecurity Web site that aggregates worthy outreach materials, and have these personnel convened to discuss how they could assist in the event of a failure in biosecurity?

5.2. Labor

Concerns about agricultural labor should go beyond the heavy presence of immigrants with little attachment to a community. While public data on migrant and undocumented labor in US agriculture are scant (Hanson, 2006), migrant employees typically originate from rural areas and may return there when on holidays. Labor from Mexico and Central America do not presently pose threats from FMD, but any trend toward more immigration from countries further south in Latin America should be a concern to the United States. Linguistic, cultural, and educational gaps may leave an employer unsure as to the extent of biosecurity risk an employee poses. Unlike crop production, animal production has become non-seasonal with the ability to retain permanent employees. However, uncertain tenure due to legal status may impede the ability of employers to secure a stable, reliable, trained workforce. Legal status matters because, for whatever reason, employers and illegal employees will be wary of government contact.

5.3. Scale, Vertical Integration, and Transportation

Within a country, industries may be structured in part to internalize incentives failures regarding disease transmission.³ Cattle production has lagged behind pig and poultry production in biosecurity measures taken. Cattle farms throughout much of the world also tend to be less integrated than large-scale pig and poultry operations. This may be, in part, due to older age at slaughter, changing dietary needs during grow-out, and use of surplus dairy calves. Transfer through sales auctions of young animals, rather than by contract or ownership from suckler herd to finish, often predominates. Imperfect downstream information on treatment history then

rationalizes private upstream decisions to avoid biosecurity costs. Biosecurity problems will be less severe if farms have reliable knowledge about the source of their animals.

Tables 5 and 6 show that there are growing internal and international shipments of live animals. Public data on trading and movements activities within the US are sparse. Whether the extent of trading should be a worry depends very much on how these animals are traded and subsequently managed. Evidence suggests that larger feedlots tend to be more careful about the animals they buy and to have better biosecurity programs in place for introduced animals, thus at least partly offsetting their greater level of exposure.

Table 7 provides circumstantial evidence for evaluation of performance across farms at different scale levels in US dairying. Productivity differentials are marked for both output level and input use efficiency. Organic (both small-scale and large-scale) and other production formats are growing and promise to be relevant components of animal production in the future. However, cost data suggest that industrial format production will continue to expand absent regulatory intervention. In many low-income countries, large animal farms are likely to emerge soon. The trend toward scale has come with a closing off of animal production systems. Accompanying features are emphasis on control, more formal information and information management, as well as more automation. Many biosecurity investments involve scale economies, be they capital investments or through specialized labor. To illustrate, consider a perimeter fence around a square production facility for which the fence costs \$10/meter. With one animal per square meter, the cost per animal is \$40 for one animal but it is \$0.4 for 10,000 animals.

Agricultural structure is an emotive topic, and care is required if objectivity is to be retained. The debate on biosecurity and production structure needs to be considered on its own merits before including this dimension in the larger picture. Vertical integration (i.e., integrating from farm to fork) often does entail transportation during an animal's growth. But many economies from vertical integration are due to a rationalized supply chain that involves fewer relocations, fewer trips to sales barns, and more closely monitored transportation. The higher-performing animals that typically exist on integrated farms may be more vulnerable to immune system shocks. Horizontal integration (i.e., larger feedlots) does involve larger losses if a risk materializes but also greater care that the loss does not materialize. Larger farms should also be easier to integrate into an emergency preparation and response system, perhaps with Internet

³ See Hennessy, Roosen, and Jensen (2005) on this point.

connections. There is a dearth of research on how production structure and behavioral response to this structure affect biosecurity risks.

5.4. Zoning and Other Land Policies

Land use externalities have long been recognized in land zoning policy formation. The provision of services to residential, commercial, industrial, and agricultural properties is cheapest when similar properties are clustered. Safety and nuisance externalities are minimized when space separates dissimilar properties. Spatial woodland policy often emphasizes variety, wildlife, and firebreaks. Proximity contributes to disease spread, and congested hog production was considered to be a factor in Taiwan's FMD outbreaks a decade ago (Huang, 2000). The mixing of species, pigs and poultry or fish species, for example, and use of communal land for grazing are also known to feature in the introduction and spread of a disease. The appropriate role for government in managing these externalities depends not only on the nature of the most likely infections but also on the effectiveness of veterinary health infrastructure, incentives facing producers, and actions available to producers.

6. Policy Alternatives

The following is a set of tongue-in-cheek policy alternatives. They are loosely sequenced by theme but are otherwise not ordered, and no firm sense of the dollar equivalent merits of these alternatives is provided. Omitted are any suggestions concerning the design of infrastructure because I am far from fully apprised on how elaborate prevention and control systems are meant to work in the United States or elsewhere.

1. *Further subsidize activities intended to reduce the prevalence of worrisome infectious animal and plant diseases in poorer near-abroad countries.* Developed country governments are involved in such activities through diverse channels, but the task of assessing donor country benefits from such international transfers is difficult. Among the challenges are data limitations, the breadth of consequences a disease can have, scientific uncertainty, and uncertainty about the efficacy of local institutions. The magnitude of gaps between performance indicators in poor and wealthy countries implies high expected social returns on such investments. One endeavor that the OIE was contemplating, as of August 28, 2006, was a Global Emergency Response Fund for Animal Epizootics and Zoonoses (GERFAE). Countries would be provided with funds to (i) compensate livestock owners who report suspicious cases of livestock disease, and (ii) cover

direct government costs of controlling an outbreak. If not already being addressed by some other mechanism, this seems like a need that should be promptly addressed within a carefully designed mechanism. The incentives put in place should encourage mainly cases of true concern to be brought forward. Also, education will determine the effectiveness of these efforts because growers need to be aware of compensation and have a good sense of what to look for.

2. *Increase participation, through subsidies or otherwise, in animal identification and tracking systems.* The US government acknowledges this need, having funded producer groups through grants to encourage enrollment. Many animal producers and processors are also acutely aware of the need. Enrollment is not enough, though. A premises registration list needs to be updated just as voter registration lists are. The voluntary approach taken in the United States will require carrots as the primary approach to premises registration, animal identification, and animal tracing. The extent of ultimate coverage and quality of information provided will depend on how producers are drawn into the system. Governments could leverage other programs they operate. Possible opportunities to expand participation are discussed in other points on this list. As of March 12, 2007, an estimated 25.8% of the estimated 1.44 million livestock farms had registered with the NAIS. But participation varies markedly across states, for example, 63% in Pennsylvania but 8% in neighboring Ohio. A \$50 check for re-registering every two years would have a maximum annual cost of \$35 million (plus administration costs) per year.

3. *Encourage trading other than through sales barns and strengthen animal transportation laws.* Production animals are moved and traded in order to better utilize feedstuffs and allow for specialization in management. These are important functions, and efforts to reduce movement should not be taken without careful consideration. Animals are traded by private treaty or through livestock markets, which are subject to oversight. They may move long distances while not changing ownership, as with pigs farrowed in one state but grown on contract elsewhere. Animal welfare considerations are leading many jurisdictions to revisit laws on trading and transporting animals.

The foremost concern in this area, and one well-understood by the US government, is the need to have better movement information, including general patterns and specific movements. Oversight at livestock marts is cursory on the whole. This is not the fault of local authorities, of overseeing veterinarians, or of anyone else; it is just the nature of marts. Respiratory and fecal contact across animal lots is almost inevitable, even when great sanitary care is taken. Costly

endemic diseases and diseases of direct concern to agro-terrorism prevention can be communicated by these means. Mansley *et al.* (2003) document the role sheep markets played in spreading the 2001 FMD outbreak throughout Britain and beyond.

In many cases, there appear to be problems with incentives alignment when monitoring livestock markets. These markets should bear monitoring costs but should not be in a position to influence judgments or recommendations. Inspectors should not be paid directly by the sales barn. Governments can encourage fewer trades and less risky trading channels through user fees, encouraging source verification schemes, or facilitating online markets that avoid channeling animals through a physical location.

4. *Seek better coordination of biosecurity outreach.* What other producers and processors do is important knowledge, as it can alter a producer's incentives to take action. In many cases, information that others are acting to secure the food system should encourage a producer to do likewise. This is likely the case when the objective is to keep a disease out of a region. Farming operations differ in many ways, including access to information on an operation's security vulnerabilities. Larger operations may have strong incentives for managers to think about security issues, if only because they have more to lose. If heavily capital intensive, then these investments may remain idle as a disease problem is being resolved. Labor-intensive farming operations, often smaller ones, can temporarily lay off workers. Biosecurity investments will often have a large fixed-cost component, which larger farms can spread over more units of production.

From the perspective of disease control, smaller, hobby, and alternative agriculture farms will likely endure as significant industry components. Providing information to these farms is important, if difficult. The US federal government and the land grant university system's provision of materials appear to be quite fragmented, perhaps because few outreach personnel specialize in the issue. A centralized Web site that those supplying research and outreach materials can send to and diverse organizations can link to would be most useful.

5. *Use existing and/or new regulatory infrastructure to require that feeding operations comply with certain biosecurity measures.* The US Clean Water Act (CWA) is administered by the Environmental Protection Agency (EPA) and by individual states. The Act allows for the regulation of point-source emissions into waterways. It covers about 15,500 confined animal feeding operations (CAFOs), including their emissions of nitrogen, phosphorus, metals, and

bacteria. Since 2003, CAFOs have needed a pollutant discharge permit. At a minimum, the permit requires capacities for managing several events relevant to biosecurity. These include the operation's approach to handling dead animals, chemicals, manure, and litter. The plan's emphasis is on water and not on biosecurity.

As with water quality, the government has public good responsibilities for controlling existing and exotic infectious animal diseases. Farms have a strong interest in remaining disease-free, but incentives may be inadequate because farms may not take account of how their actions affect other farms. Fencing, access control, quarantine facilities, sanitation equipment, and disposal of potentially infectious materials are among best management practices (BMPs) the state might seek to encourage. While the CWA would likely not be a suitable point of departure, and the EPA may not be the appropriate agency, any federal efforts to encourage biosecurity should not be burdensome. Mandatory participation for smaller units may not be practical, even if politically feasible.

6. *Provide subsidies for the cost of installing assets that promote on-farm biosecurity.* The Environmental Quality Incentives Program (EQIP) was reauthorized in the 2002 farm bill as a voluntary approach to environmental conservation practices by producers. It offers technical assistance and cost-share subsidies for adopting environmentally friendly practices, and priorities include reducing point source pollution emissions from CAFOs. A similar program to encourage biosecurity BMPs should be as practical to implement.

7. *Provide insurance to growers for major disease outbreaks, and use the insurance to promote biosecurity BMPs.* Economists are often reluctant to encourage intervention in insurance markets because such interventions can create or exacerbate moral hazard problems. Put simply, if a grower is insured then she may be less inclined to protect the farm against disease entry. However, the government may feel obliged to compensate smaller producers in the event of a major disease outbreak. This is in part to encourage reporting, but it can also be in response to political pressures. In the event of a disease outbreak, and were government compensation not provided, many farmers who did take considerable care could face bankruptcy. The disease might be very contagious, or their healthy animals might be condemned as a precautionary measure.

The strong possibility that the government would compensate might undermine prospects for a viable private insurance market, but it could be nearly impossible for a government to credibly

convey that it will not intervene. In addition, insurance markets are much better at insuring isolated events (e.g., house fires, auto thefts) rather than systemic events (e.g., floods). Insurance companies are very reluctant to insure for poorly understood contingencies that can result in widespread losses. So the question then is how the government can leverage its implicit commitment. Conveying to all at an early stage that compensation beyond a certain minimum level will be given only to those who participate in premises registration and comply with certain monitorable biosecurity BMPs may be one way of doing so.

8. *Revisit food irradiation.* There is a consensus that food irradiation may affect the nutrition content of food but that the treated food is safe to consume. It is permissible to irradiate meat, poultry, and some other foods in the United States. Federal regulations require that irradiated foods be labeled, and this (together with the unfortunate name) has turned consumers off. One wonders the extent to which irradiation could be used to free up resources to better secure foods in other ways.

9. *Facilitate the professionalization of biosecurity management as a career.* In light of demand for personnel in the area, schools of public health have responded by providing programs that include biosecurity as a major emphasis. Curricular materials were likely taught in other courses, and individuals may already have acquired this breadth of knowledge. However, recognition that a common body of knowledge should be relevant to the careers of a significant group of people portends more than a convenient packaging of materials. It provides a vision for a discipline, just as accountancy and engineering emerged out of the Industrial Revolution.

Graduates may form networks and societies for career promotion, continuing education, and accreditation. Hiring firms are provided with the view that the biosecurity function merits specialization. A more coherent and informed demand for technical improvements in the area can lead to new products and product adaptations, as well as demand for research. The public sector has a role in this in that it will need many biosecurity professionals in coming years. At the state level, public universities decide what majors and minors are taught. For the United States, where professionalization in this area seems to be underway, perhaps the best way to promote the trend is to give separate titles to biosecurity aspects of legislation and regulations so that firms see how others view the issue.

10. *Encourage developments in economic epidemiology.* A variety of policy topics in recent years, including invasive species, have pointed to deficiencies in this area. The world needs a

deeper stock of epidemiologists with a good sense of economic principles as well as economists who are strong in the natural sciences. Perhaps a joint Ph.D program at a school of public health could be partly funded by or integrated with the Centers for Disease Control and Prevention.

11. *Prepare for a major crop failure.* While US corn yield variability appears to have declined in recent years, corn production can fluctuate by 30% or more year to year with drought or floods. A natural event or biosecurity attack that had a significant effect on crop supplies is more likely to seriously disrupt food and animal feed markets than was the case in the recent past. This is because newly installed ethanol production plants are likely to have inelastic short-run demand for feedstock and may outbid livestock producers.

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Table 1. Farm-Level Cash Receipts by Commodity in United States, 2005

Commodity	Value of Receipts, in \$ Billion	% of Total Receipts	Cumulative %
All commodities	239	100.0	
Livestock and Products	125	52.3	
Crops	114	47.7	
1. Cattle and calves	49.2	20.6	20.6
2. Dairy products	26.7	11.2	31.8
3. Broilers	20.9	8.7	40.5
4. Corn	19.1	8.0	48.5
5. Soybeans	16.8	7.0	55.6
6. Greenhouse/nursery	16.2	6.8	62.3
7. Hogs	15.0	6.3	68.6
8. Wheat	6.8	2.9	71.5
9. Cotton	5.8	2.4	73.9
10. Hay	4.7	2.0	75.9
11. Chicken eggs	4.0	1.7	77.6
12. Grapes	3.5	1.4	79.0
13. Turkeys	3.2	1.3	80.3
14. Potatoes	2.4	1.0	81.3
15. Almonds	2.3	1.0	82.3
16. Tomatoes	2.3	1.0	83.3
17. Lettuce	2.0	0.8	84.1
18. Oranges	1.6	0.7	84.8
19. Apples	1.6	0.7	85.4
20. Rice	1.6	0.7	86.1

Source: National Agricultural Statistics Service.

**Table 2. United States Agricultural Exports in
\$ Billion, 2005**

Product	
Live Animals	0.6
Red Meats & Products	4.3
Poultry Meats & Products	3.0
Dairy Products	1.7
Hides & Skins	1.8
Wheat	4.3
Rice	1.3
Corn	4.8
Soybean	6.3
Fruits, Nuts, Etc.	6.4
Vegetables & Products	5.8
Cotton	4.0
Total, incl. other Ag. Exp.	63.0

Source: U.S. Agricultural Trade Update, ERS, USDA, Feb. 13, 2007.

Table 3. Economic Losses that Could Arise in Natural or Terrorism Biosecurity Attack

Subject	Type, Ex	Ability to measure	Comments
On-farm production	ante	Very rough	Biosecurity costs may have multiple purposes. Regulatory burden highest on small farms.
	post	Very rough	Compensation for slaughtered animals is a transfer, where true cost is that of raising taxes. If insufficient compensation, efficient farmers may exit. Losses if disease becomes endemic disease. Loss of genetic resources. Resources can be re-allocated to other uses.
Domestic market	ante	Very rough	Some costs passed on to consumers.
	post	Very rough	Some costs passed on to consumers. Producers of other foods may gain. Will consumers behave in rational manner?
Int'l markets	ante	Very rough	Transaction costs at border mean losses from reduced trade and technology transfer.
	post	Very rough	Resources used for other purposes.
Government	ante	Maybe	Administration costs. Dead-weight loss of taxation. How well does government prioritize risks? Terrorism makes prioritization more difficult.
	post	Maybe	Administration costs. Dead-weight loss of taxation. Loss of credibility. Focus taken from other issues. Bunched terrorist attacks increase cost of preparation.
Mortality & quality of life	ante	Maybe	People may avoid foods they believe to be risky.
	post	Maybe	Can science adequately identify consequences? Who decides on loss due to impaired person?
Food & Agri-input sectors	ante	Very rough	Biosecurity costs may have multiple purposes. Regulatory burden highest on small businesses.
	post	Very rough	Lost markets, and few alternative uses of resources in capital intensive sectors. Low political will to compensate?
Other sectors	ante	Very rough	Business travel and tourism more expensive, but people do other things with resources.
	post	Very rough	Local tourism costs can be high. Where do clean-up resources, etc., come from?
LDCs	ante	Very rough	Trade barriers cause lower export prices, higher import prices.
	post	Maybe	Lower stocks for food relief in famine.
Individual liberty	ante	Hard	Where to start?
	post	Hard	
Animal welfare	post	Maybe	Who decides on loss due to dead animal?

Note: With all ex post losses, one needs to distinguish between assessing loss due to a realized biosecurity breakdown and expected ex post losses. Assessing the ex ante probabilities over different realizations of physical losses will, in general, be very difficult because of unknowns about the nature of risks and vulnerabilities of response infrastructure.

Table 4. Number of Farms in United States, by Enterprise, in thousands

Enterprises engaged in	1974	2002
Beef Cows	1,025	796
Dairy Cows	404	92
Hogs	470	79
Broilers	34	32
Grain Corn	883	349
Wheat	534	170
Soybeans	542	318

Source: US Census of Agriculture.

Table 5. Internal (State-to-State) Live Animal Shipments (Million Head and Percentage of Inventory), United States

Item ^a	1980	2005
Cattle	20.0 (18.0%)	20.8 (21.8%)
Pigs	4.6 (7.1%)	33.4 (54.8%)
Sheep	2.2 (17.3%)	1.5 (24.3%) ^b

Source: National Agricultural Statistics Service.

^a Percentage of annual inventory data are in parentheses. Cattle inventory percentage is for January 1 inventory of all cattle and calves. Pigs inventory percentage is for December 1 inventory of all hogs and pigs. Sheep inventory percentage is for January inventory of all sheep and lambs.

^b The 2005 sheep data are for 2004, the last reported year.

Table 6. World-Wide Exports of Live Animals (Million Head)

Item	1981	2004
Cattle	7.3	8.0
Pigs	9.6	22.7
Sheep	15.8	14.8
Chickens	366.2	816.9
Turkeys	14.6	64.0

Source: FAO, Agricultural Data, Agriculture and Food Trade.

Table 7. Summary of ARMS 2000 Dairy Survey Data

Summary statistic, all are averages	Enterprise Size		
	Medium 50-99	Large 100-499	Industrial ≥ 500
Herd size	88	313	955
Output/cow (lb/year)	16,157	17,420	17,326
Labor efficiency (hours/100 lb milk)	0.44	0.19	0.11
Feed efficiency (lb. feed/ 100 lb milk)	252	317	162
Veterinary expenses (\$/100 lb milk)	0.71	0.58	0.60

Note: Data are as reported in tables 4 and 5 of Short (2004).