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RESPONDING TO HEALTH RISKS ALONG THE VALUE CHAIN

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Responding to Health Risks along the Value Chain

PIPPA CHENEVIX TRENCH, CLARE NARROD, DEVESH ROY AND MARITES TIONGCO

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Contents

1. Introduction . . . 7
   - 1.1 Increasing food safety risks . . . 8
   - 1.2 Impact of food safety risks on the poor . . . 9
2. Key health risks along the value chain . . . 10
   - 2.1 Health risks along the value chain . . . 12
   - 2.2 Microbiological hazards . . . 12
   - 2.3 Chemical contaminants . . . 15
   - 2.4 Occupational Health . . . 17
3. Drivers of Change Affecting Food Safety . . . 18
   - 3.1 Consumer demand and willingness to pay for safer foods and reduced risks . . . 19
   - 3.2 Modern value chains and the demand for safe foods . . . 19
4. Challenges to the Poor in the Face of Increased Health Risks Along the Value Chain . . . 24
   - 4.1 Problems facing producers . . . 24
   - 4.2 Specific problems faced by smallholders in complying with food safety requirements . . . 27
   - 4.3 Problems facing consumers . . . 30
5. Using a Modified Risk Analysis Approach to Reduce Food-Borne Hazards and Improve Health and Market Access for the Poor . . . 31
   - 5.1 The components of modified risk analysis . . . 32
   - 5.2 Food safety demand and hazard identification . . . 32
   - 5.3 Risk assessment . . . 35
   - 5.4 Evaluation of risk management options at different points along the value chain . . . 36
   - 5.5 Assessing uptake . . . 38
6. Current and Emerging Opportunities for Cutting Health Risks Discussion along the Value Chain . . . 39
   - 6.1 Addressing problems arising from asymmetry of information . . . 40
   - 6.2 Addressing problems of market power inequities . . . 42
   - 6.3 Addressing problems of political power and government failure . . . 45

6.4 Identifying cost-effective risk-based technologies to reduce health risks along the value chain . . . 45
7. Conclusion . . . 46
References . . . 48

List of Tables

Table 1. Average annual growth in global per capita consumption of various food items (%) . . . 7
Table 2. Microbiological hazards, sources, and symptoms (listed in order of frequency) . . . 13
Table 3. Naturally occurring plant toxins . . . 15
Table 4. Select pesticides and associated health impacts . . . 16
Table 5. Select environmental chemical contaminants and their health implications . . . 17
Table 6. Examples of consumers' willingness to pay (WTP) for food safety attributes . . . 20
Table 7. Examples of research on costs of compliance . . . 26

List of Figures

Figure 1. Possible sources of food contamination along milk and grape value chains . . . 11
Figure 2. Drivers of change along the value chain . . . 18
Figure 3. Modified risk analysis framework
Figure 4. Mean aflatoxin levels in farmer samples of groundnut in Western Mali (ppb) . . . 35
Figure 5. Potential places in which aflatoxin risk may be detected as maize moves along the value chain . . . 35
Figure 6. Risk reduction-cost trade-off . . . 37

Glossary of terms and Abbreviations

Source: United Nations Food and Agriculture Organization and World Health Organization 2009, p. 125.

BSE – Bovine spongiform encephalopathy

DALY –Disability - Adjusted Life Year. A measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.

Exposure assessment – The qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources.

Hazard – A biological, chemical, or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard characterization – The qualitative and/or quantitative evaluation of the nature of the adverse health effects associated with the hazard.

Hazard identification – The identification of biological, chemical, and physical agents capable of causing adverse health effects which may be present in a particular food or group of foods.

HPAI – Highly Pathogenic Avian Influenza

LDC – Less developed country

Risk – A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard in food.

Risk analysis – A process consisting of three components: (a) risk assessment, (b) risk management, and (c) risk communication.

Risk assessment – A scientifically based process consisting of the following steps: (a) hazard identification, (b) hazard characterization, (c) exposure assessment, and (d) risk characterization.

Risk characterization – The process of determining the qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization, and exposure assessment.

Risk communication – The interactive exchange of information and opinions concerning risk and risk management among risk assessors, risk managers, consumers, and other interested parties.

Risk management – The process of weighing policy alternatives in the light of the results of risk assessment and, if required, selecting and implementing appropriate control options, including regulatory measures.

SPS – Sanitary and Phytosanitary

Supply chain – Network of entities directly or indirectly interlinked and interdependent in serving the same consumer or customer. A supply chain underlies a value chain and consists of: (a) vendors that produce and/or supply raw materials, (b) producers who convert the material into products, (c) warehouses that store the products, (d) distribution centers that deliver to retailers, and (e) retailers who bring the product to the consumer.

Value chain – The successive stages, and interlinked activities, during which value is created and/or added when producing, distributing, and servicing a product that, in turn, adds to the bottom line and helps to create competitive advantage. Distinct stages in the value chain may include: (a) producing, receiving, and/or distributing raw materials, (b) converting raw materials into a finished product, (c) identifying customers and distributing the product, and (d) providing customer support. Identifying the value chain allows an entity to refine operations in an effort to improve quality, add efficiencies, and increase profits.

WTP – Willingness to Pay

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

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Responding to Health Risks along the Value Chain

PIPPA CHENEVIX TRENCH, CLARE NARROD, DEVESH ROY AND MARITES TIONGCO

1. Introduction

SAFE FOOD IS NOT A LUXURY; IT IS AN ESSENTIAL COMPONENT OF FOOD SECURITY. IN developing countries, consumption of unsafe food and water continue to be one of the major causes of preventable morbidity and mortality, especially due to malnutrition, food- and water-borne diseases, and associated economic loss to the individual, family, and society (WHO 2009). Furthermore, as impaired human health has been shown to lead to reduced labor productivity and lower returns to human capital accumulation (including schooling and training), these problems affect livelihood outcomes in both the short and the long run.

While poverty persists, the proportion of people in developing countries living on more than two dollars a day has increased significantly over the past three decades (from 31 percent in 1981 to 53 percent in 2005 (World Bank 2010). In China, the proportion of people living on less than $2 a day fell from 98 percent to 36 percent, between 1981 and 2005. Per capita income has grown from 2002 to 2009 at an average rate of more than 8.7 percent per year in the developing countries of East Asia and the Pacific, and at over 6.0 percent per year in the developing countries of South Asia (Narrod et al. in press; see appendix). This growth in income has not been uniform across the globe or within countries. Incomes in East Asia and Pacific have increased, but South Asia has seen only a modest change, while in Sub-Saharan Africa the number of people living on less than $2 a day has remained nearly static, falling from 74 to 73 percent (World Bank 2010).

Alongside economic growth, there has been a continuous process of urbanization, particularly in the developing countries. From 1975 to 2010, urban populations in developing countries have grown at an annual rate of 3.1 percent, compared to 1.2 percent in developed countries (Narrod et al. in press). In 2009, the proportion of urban dwellers passed 50 per cent: for the first time in history, the world has more urban than rural dwellers (United Nations 2010).

These changes in wealth and in population distribution are having profound impacts on the worldwide demand for high-value food products such as meat, milk, fish, fruits, vegetables, and processed and prepared foods (see Table 1; Hall et al. 2004). These products are highly perishable and susceptible to food safety risks as they move along the value chain prior to consumption.

Table 1—Average annual growth in global per capita consumption of various food items (%)

Food Item	1962-1971	1972-1981	1982-1991	1992-2001	2002-2007	1962-2007
Cereals (excluding beer)	0.4	0.7	0.3	-0.3	-0.1	0.3
Fruits (excluding wine)	1.4	0.7	0.6	1.4	24	1.3
Pulses	-2.5	-1.3	-0.3	0.4	1.2	-0.9
Vegetables	-0.2	1.3	1.2	3.9	1.1	1.5
Eggs	1.4	0.8	1.7	2.5	0.9	1.4
Fish, Seafood	2.0	0.4	1.1	2.4	0.8	1.4
Meat	1.7	1.0	1.2	1.2	0.8	1.2
Milk (excluding butter)	0.1	0.2	0.1	0.6	1.5	0.3

Source: Narrod et al. (in press) based on FAOStat data downloaded November 2010.

1.1 Increasing food safety risks

As populations in developing countries become increasingly urbanized, a significant proportion of fresh produce consumed in the cities is grown in the urban and peri-urban areas. Many of these farms depend for irrigation on waste water or on water sources likely to be contaminated by municipal wastes containing pathogens and non-microbial contaminants (IMWI 2006). The International Water Management Institute (IWMI) estimates that 3 to 3.5 million hectares of agricultural land in developing countries are being irrigated with raw or diluted wastewater (Scott et al. 2004; Water Policy Briefing 2006). Increased global food production has largely been fueled by increased use of pesticides, herbicides, and other chemicals. Demand for products with specific cosmetic attributes (such as spotlessness and lack of blemishes), particularly by the urban consumer, has further encouraged excessive use of pesticides and chemical fertilizers (Okello et al. 2010). Such products may pose significant health risk to producers and workers if not used properly, and to consumers if applied in excess or at the wrong times.

Emerging zoonotic diseases are likewise of major concern, particularly in developing countries where such diseases and their causes are often not recognized because of the lack of diagnostic capacity along the value chain as well as poor infrastructure (Narrod et al. 2010). It has been estimated that 70 percent of the world's rural poor depend on livestock, poultry, and many other animals (such as working elephants, donkeys, and dogs) as a component of their livelihoods (LID 1999; FAO 2002). According to the World Bank (2010), "the direct costs of zoonotic diseases over the last decade surpassed US$20 billion—including public and animal health service costs, compensation for lost animals, and production and revenue losses to the livestock sector, and over US$200 billion of indirect losses to affected economies as a whole."

With rising incomes and shifting consumption patterns, we also see an increase in demand for food safety and quality, and increased technological ability to monitor for safety attributes (Narrod et al. in press). Though this trend towards demanding foods with specific attributes may be more apparent in the developed world, there is also a growing demand from wealthy consumers in the developing world (Mergenthaler et al. 2009). Because of the perishability of many high-value products, and concern over the spread of diseases, many of these products are subject to stringent safety requirements in the developed world. Currently, however, most developing countries lack credible institutional mechanisms and affordable testing methods to monitor for such hazards and to ensure that these highly perishable products remain safe from a health standpoint, as the product moves through the value chain.

Recognizing the limits of local institutions in developing countries to monitor for such health hazards, multi-national food companies, as well as industry and export promotion organizations, are increasingly setting and relying on private food quality and safety standards. These multi-national agrifood companies, including producers, processors, and retailers, have established operations in many developing countries to meet both domestic and international demand (Narrod et al. 2007). Because these larger, more global enterprises have reputations to maintain, they have an incentive to develop and apply high quality and safety standards, to ensure the delivery of products that provide an acceptable level of risk protection to their high-end markets.

For poor farmers in less developed countries (LDC), whose comparative production advantage in many types of food products derives mainly from growing conditions and cheap labor, the emergence of a local market for high-value food and the globalization of food markets offers both a great opportunity and a major challenge. To the extent that value-added products often command a higher price than traditional staples in many markets, poor producers in developing countries are often drawn by the financial lure of producing these goods—without understanding the difficulties associated with producing for distant markets (Eaton and Shepherd 2001). Higher standards usually require more intensive management that implies higher costs. Many small-scale producers are squeezed out of this market due to low productivity, inadequate human and technical capacity, remote location, inability to meet private standards, or limited competitiveness vis-à-vis larger growers. Often the big corporations prefer to source from a limited number of large farmers, who may or may not contract out to smaller farms (Dolan and Humphrey 1999). Thus, while the private sector plays a vital role in facilitating the establishment of supply networks and ensuring that the suppliers in the South meet the demand requirements of the industrialized North (as well as higher-end domestic markets), these improved production processes may not extend to small producers. Moreover, within developing countries, the lack of a price differential favoring products grown in a safe manner creates little incentive for farmers to invest in technologies or infrastructure required to produce and process food safely.

Even where small farmers are left out of lucrative high-value markets, they continue to contribute a large share of agricultural production within LDCs. Most of their production and sales occur in an unorganized manner rather than within formal value and supply chains. In such cases, the burden from a human health perspective falls not so much on the producers, but on consumers, who are at an increasing risk of exposure to health hazards due to rapidly changing production practices, a lack of human and institutional capacity, and poor oversight by governments and their agencies, exacerbated by limited public health awareness. Mycotoxins, for example, such as fumonisin and Aflatoxin, are found in many staple crops. But although Aflatoxin has been listed as a Class A carcinogen that causes liver cancer, and has been associated with immune-suppression and stunting in children (Gong et al. 2003, 2004), very few developing countries monitor for it in informal markets.

The impacts of food and water safety challenges in developing countries affect not only the health of the poor (as producers, workers, or consumers), but also their level of income and protection of assets, including livestock assets. Highly visible food safety issues, associated with outbreaks or other incidents that acutely threaten human health or life, usually claim the spotlight among ministries and the media. But the more significant threats in terms of aggregate impact over time are perhaps the less visible, chronic impacts of unsafe food, for both people and animals. The Center for Disease Control (CDC) estimates that over 4.5 billion people may be chronically exposed to aflatoxins. Moreover, it has been widely documented that the use of untreated wastewater generates health risks including intestinal parasites and bacterial and viral infection that may lead to cholera and typhoid epidemics, as well as cancer and congenital problems (Scott et al. 2004). The World Health Organization (WHO) reports an estimated 1.9 million deaths and 64.2 million disability adjusted life years[1] (DALYs) lost worldwide per year due to unsafe water, lack of hygiene, and insufficient sanitation (WHO 2009). This attributable burden of disease comprises 4.2 percent of worldwide DALYs[2] and ranks among the top ten leading risk factors worldwide (WHO 2009).[3]

Livestock supports the livelihoods of 800 million to 1 billion of the world's poor and landless (Livestock in Development (LID), 1999; Thornton et al., 2000). It is not only an important income-generating asset, but also an indicator of status and wealth, a source of food and nutrition security, and a means of insuring against future shocks and stresses (see Randolph et al. 2007). The consumption by livestock of unsafe feed (such as mycotoxin-contaminated maize or cottonseed) and contaminated water therefore has an impact on livestock productivity and on the livelihoods of the poor who depend on these animals—as do the various zoonotic diseases (such as avian flu and bovine spongiform encephalopathy (BSE). Infections of Highly Pathogenic Avian Influenza (HPAI) H5N1 resulted in the destruction of more than 140 million birds in South East Asia alone, with costs estimated in excess of US$ 10 billion (World Bank 2005).[4] The effect of such a disease can be many times higher if it evolves into a human pandemic. It has been estimated, for example, that an HPAI pandemic could lead to global economic losses in the region of US $800 billion (World Bank 2005).

For animal diseases such as avian flu in poultry or brucellosis in cattle, producers suffer negative impacts on livelihoods from the costs of prevention, culling, and other controls. This loss is compounded by the negative effects on demand. In the case of Highly Pathogenic Avian Influenza, Roy et al. (2010) found that the demand shock (that is, the reduction in demand due to consumer panic and an associated fall in the price of poultry and eggs) far outweighed the supply shock (the reduction in numbers of poultry as a result of disease mortality or control measures). Demand shock is generally not localized—and, most importantly, it can occur even in the absence of an outbreak, as a perception-based consumer response.

While higher quality and safer food can lead to better returns for farmers, improved safety alone does not always mean higher margins; market failures often prevent small-scale farmers from accessing these markets. And for local, national, and even regional markets in the developing world, it is not clear whether consumers can or will support the additional costs associated with producing safe food, or whether regulatory agencies can both require and enforce tighter controls without hurting lower-income consumers or producers.

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[1] The **disability-adjusted life year (DALY)** is a measure of overall disease burden, expressed as the number of years lost due to ill-health, disability, or early death.

[2] Computed from statistics at: http://www.who.int/whr/2002/annex/en/index.html.

[3] The estimated annual medical costs/productivity losses due to the 7 major foodborne pathogens range from $6.6 billion to $37.1 billion, according to USDA and Centers for Disease Control and Prevention (CDC) figures.

[4] Recent studies conducted in developing countries show that among the rural poor small-scale poultry producers, poultry income contributes the most to the livelihoods of the poorest segments (see Maltsouglou and Rapsomanikis 2005; Roland-Holst et al. 2007; Birol and Asare-Marfo 2008). Hence their incomes are potentially affected the most by AI outbreaks and scares.

1.2 Impact of food safety risks on the poor

While all countries share similar concerns about the health risks associated with unsafe food, specific risks are perceived and managed differently in relation to prevalence of food safety issues, political will, and institutional capacity to reduce such risks. A country's risk management profile varies with climate, diets, income, public infrastructures, and governance (Unnevehr 2003).

The poor are at highest risk of exposure to unsafe food, and since malnourished and nutrient-deficient children are most susceptible to the health risks associated with food or water, they have the most to gain from improvements. Ironically, however, the existing inequality of exposure risks is in fact exacerbated by safety standards that are differentiated according to the end market. Furthermore, poor farmers are most vulnerable to losing market access when food safety requirements become tighter.

It is important to ensure that the poor benefit as well from the policies, approaches, and technologies designed to reduce human health risks derived from food or water-borne hazards. This challenge will require research, monitoring, education, and investment:

1. Better food-borne disease surveillance and testing, both as the food moves along the value chain and in clinics and hospitals
2. Analysis of the risk, how it alters along the value chain, and how control methods and management practices affect that risk
3. Better understanding of policies, regulations, and institutional mechanisms that may promote or prevent exposure to risk
4. Better understanding of factors affecting the behavior of value-chain actors and consumers
5. Education on the health risks associated with consuming unsafe food
6. Investment in hard and soft capacity, in low-cost management practices and technologies, and in education to ensure their uptake by value-chain actors and consumers

Such approaches will differ according to markets, infrastructure, and the governance of institutions to ensure food and water safety.

A risk-based approach is essential to understanding how exposure to health hazards varies as agriculture products move and are handled and processed throughout the value chain from farm to table—and an essential step toward improving the livelihoods of the world's poorest. Such an approach requires: (a) an understanding of the opportunities and constraints to reducing risks as products move along the value chain; (b) partnerships between stakeholders (producers, value-chain actors, consumers, agriculture and health ministries, and private industry); and (c) the support of the national and international community.

Chapter two outlines the importance of considering health risks within the context of the commodity systems and value/supply chains, and describes the health risks that typically exist along any productive agrifood chain. Chapter three identifies the primary economic and institutional factors driving the demand for greater food safety standards and reducing health risks along value chains. Chapter four identifies the impacts on poor producers, consumers, and others of these health risks, as well as the mechanisms to mitigate these risks, such as the development of food safety standards. Chapter five reviews a modified risk analysis research approach developed by IFPRI to identify cost-effective ways to reduce food safety risks as agricultural products move along the value chains, both for value-chain actors and for consumers. Examples come from a series of studies of highly pathogenic avian influenza (HPAI) in Kenya, Ethiopia, Nigeria, Ghana, and Indonesia and from an ongoing program analyzing aflatoxin contamination of maize and groundnuts in Mali and Kenya. Finally, chapter six describes current and emerging opportunities for reducing human health risks along the value chain, by addressing problems of market failures, asymmetry of information, government and policy failures, and the need for low-cost effective technologies to mitigate health risks.

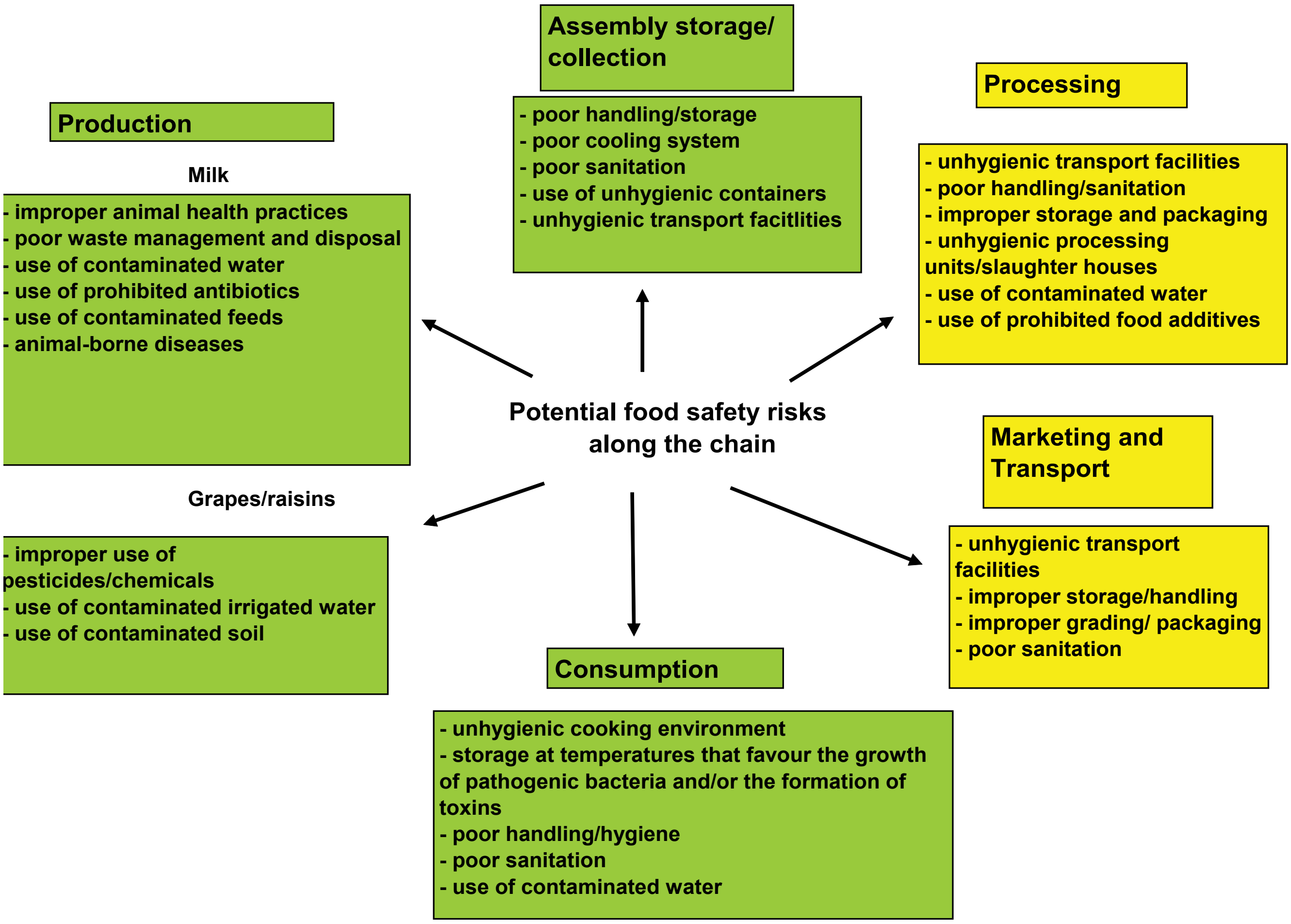
2. Key health risks along the value chain

Foodborne illness usually arises from improper practices around the production, handling, preparation, or storage of food. The changing organizational structure of the agrifood system—inputs, production, distribution, and consumption—is coupled with increasing concern about the reliability of such systems to deliver safe food to consumers in both developed and less developed countries. The value-chain approach is an effective way to evaluate the performance of food safety systems and the varying level of risk as products move along the value chain.

A value chain, as defined by Kaplinsky and Morris, consists of "the full range of activities which are required to bring a product or service from conception, through the different phases of production, delivery to final consumers, and final disposal after use" (Kaplinsky and Morris 2001: 4). As the product passes through several stages of the value chain, from pre-production to production, and to processing, marketing, and consumption, the value of the product changes and food safety risks may alter. Furthermore, the profit margin will vary as products move along the value chain, so different actors will have different incentives to alter food safety risks. In developing countries there are numerous value chains serving formal and informal domestic markets as well as export markets, and the governance of these chains varies. Understanding the relationships, networks, skills, and coordination mechanisms to manage the flow of products is essential to ensuring the delivery of safe food (Rich and Narrod 2005). Understanding how the organization and governance of value chains affects food safety in developing countries requires identifying, for example, how risks change at different stages along the chain, how price margins may impact a specific actor's willingness to alter that risk, and where information, technology, regulation, financing, and other ancillary services play a role in reducing that risk.

Figure 1 illustrates the complexity of the health hazards that arise as a product moves along the value chain, showing possible sources of food contamination along the grape and milk value chains in Uzbekistan. The issues shown in this example apply equally to many other products, anywhere in the world. For milk, risk factors leading to the growth of pathogenic bacteria occur throughout the value chain: at the farm (from unhygienic practices in milking, poor handling/sanitation, absence of cooling storage facility); at the collection center (from human hands coming in contact with the milk, the use of contaminated water for cleaning containers and implements, the absence of refrigerated storage, and delay in transporting the milk); and at the consumption stage of the chain (from the use of contaminated water for cleaning cooking utensils, the lack of effective refrigeration, and storing for too long) (Birol et al. 2008). Coordination is essential among the value-chain stakeholders involved at different stages to reduce health risks.

Figure 1—Possible sources of food contamination along milk and grape value chains



Note: hazard is any biological, chemical or physical agent with the potential to cause an adverse health effect.

Source: Birol et al. 2008.

When a specific value chain is identified as having a contamination problem, strict standards may affect which actors can participate in different markets. For example, salmonella outbreaks in the U.S. from cantaloupes imported from Mexico led to stringent food safety standards, resulting in a divergence among value-chain actors: small farmers no longer had access to the U.S. export market and instead marketed their produce in local domestic markets, which had lower food safety requirements (Avendano et al., forthcoming).

2.1 Health risks along the value chain

Health risks along agrifood value chains fall into three broad categories:

- Microbiological hazards (includes *food-borne pathogens* and *zoonoses*)
- Physical and chemical contaminants (includes *natural toxicants*, such as plant toxins and mycotoxins; *environmental contaminants*, such as mercury and lead; *externally introduced chemical contaminants*, such as pesticides, steroids, antibiotics, and food additives; and *physical contaminants* (such as shards of glass or dust from handling and processing)
- Occupational hazards

These categories are not mutually exclusive. Chemical contaminants also pose an occupational hazard, where farm workers are exposed to pollutants such as pesticides; similarly, microbial pathogens found in waste water irrigation systems can affect farm workers. By 2006, it was estimated that 20 million ha were irrigated with wastewater globally, an area nearly equivalent to 7 percent of the total irrigated land in the world (WHO 2006). The use of wastewater for crop irrigation in urban and peri-urban contexts is increasing, both as clean water becomes less available and as demand for vegetables and fruits in urban areas increases (Drechsel et al. 2006). This practice presents health risks both for the producers who are exposed to contaminated water, and for consumers buying products that are biologically or chemically contaminated. Contaminated water and food-borne pathogens have an impact on animal as well as human health. They can thus affect rural and urban livelihoods in multiple ways requiring a multisectoral approach to address sanitation and production practices.

The following sections provide an outline of the hazards that compromise food and water safety for producers and consumers, particularly in LDCs; it is by no means exhaustive.

2.2 Microbiological hazards

The WHO estimates that in 2004 unsafe water, together with inadequate hygiene and sanitation, was responsible for 1,908,000 deaths and the loss of 64,240,000 Disability Adjusted Life Years (DALYs) (WHO 2009). In developed countries, food-borne pathogens are responsible for millions of cases of infectious gastrointestinal diseases each year, costing billions of dollars in medical care and lost productivity (Fratamico et al. 2005); in developing countries, these cases often go unreported. Table 2 summarizes the main food- or water-borne diseases, including pathogens and their toxic by-products, particularly affecting high-value products.

Taylor et al. (2001) estimate that 75 percent of emerging diseases and 61 percent of pathogens known to affect humans are zoonotic in origin. Zoonoses may originate from wild as well as domestic species and are considered a growing threat in both cases. In the case of wild species, growing human populations are increasingly disturbing the natural habitats of carriers of zoonotic diseases such as bats and monkeys, increasing the risks of domestic livestock, and human, exposure (Daszak et al. 2001). Because zoonotic agents circulate between animals, humans, and the environment, the costs of disease affects not only human activity and health, but also other sectors: livestock production, pet ownership, the food and textile industry, tourism, land use, foreign trade, and consequently, Gross Domestic Product (GDP) (Narrod et al. 2010). The World Bank (2010) estimates the costs of zoonotic diseases between 2000 and 2010 to be in excess of US$20 billion (including human and animal health service costs, compensation for lost animals and production, and revenue losses to the livestock sector). When indirect costs are included, the costs to LDCs increase to over $200 billion (World Bank 2010).

Table 2—Microbiological hazards, sources, and symptoms (listed in order of frequency)

Disease/Illness Name	Pathogen Name	Category	**Food/Water Source**	**Symptoms**
Salmonella	*Salmonella spp.*	Bacterium	Beef, poultry, milk, eggs; carried in animal feces	Abdominal cramps, diarrhea, fever
Echinococcosis	*Echinococcus spp.*	Parasite	Pork, goat, sheep, other free-grazing ruminants, small rodents	Slow-growing cystic masses in vital organs
Staphylococcal Intoxication	*Staphylococcus spp.*	Toxin (Exotoxin)	Dairy products, pastries, meat and meat products	Cramps, diarrhea, severe nausea, vomiting
Campylobacteriosis	*Campylobacter spp.*	Bacterium	Raw or undercooked poultry meat	Abdominal cramps, diarrhea, fever, nausea, vomiting
Verotoxigenic [Enterohaemorrhagic] E. Coli	*Escherichia coli*	Bacterium	Meat and meat products	Abdominal cramps, diarrhea, Hemolytic Uremic Syndrome (HUS)
Listeriosis	*Lysteria monocytogenes*	Bacterium	Raw vegetables and meat, processed food contaminated before packaging, unpasteurized milk	Convulsions, diarrhea, fever, headache, loss of balance, muscle aches, nausea
Cholera/Gastroenteritis	*Vibrio spp.*	Toxin (Exotoxin)	Contaminated water, seafood (esp. shellfish); wound exposure to contaminated water	Abdominal pain, diarrhea, vomiting
Shigellosis	*Shigella spp.*	Bacterium	Contaminated seafood and fresh produce	Abdominal pain and cramps, diarrhea, dysentery, fever, nausea, tenesmus
Cryptosporidiosis	*Cryptosporidium parvum*	Parasite	Contaminated food and water; carried in animal feces	Abdominal cramps, diarrhea, fever, nausea
Rotaviral Enteritis	*Rotavirus*	Virus	Contaminated food and water; carried in animal feces	Diarrhea, fatigue, fever, muscle aches, nausea, stomach cramps, vomiting
Viral Intestinal Infections	*Calcivirus (including Norovirus)*	Virus	Contaminated food and water; carried in animal feces	Diarrhea, fatigue, fever, muscle aches, nausea, stomach cramps, vomiting
Brucellosis	*Brucella spp.*	Bacterium	Unpasteurized dairy products	Back pains, fever, headaches, physical weakness, sweating
Giardiasis	*Giardia lamblia*	Parasite	Contaminated food and water; carried in animal feces	Abdominal cramps, diarrhea, nausea
Cyclosporiasis	*Cyclospora spp.*	Protozoan	Contaminated food and water; carried in animal feces	Diarrhea, fatigue, fever, muscle aches, nausea, stomach cramps, vomiting
Toxoplasmosis	*Toxoplasma gondii*	Parasite	Contaminated food and water; in utero, and from organ trans-plants and blood transfusions	Flu-like symptoms, muscle aches/pains, swollen lymph glands
Leptospirosis	*Leptospira interrogans*	Bacterium	Contaminated food, water, or soil from the urine or semen of an infected animal	Abdominal pain, cramps, diar-rhea, jaundice, nausea, rash, severe headache, vomiting
Clostridium perfringens Intoxication	*Clostridium perfringens*	Toxin (Exotoxin)	Raw or undercooked beef or pork, carried in animal feces	Abdominal cramps, diarrhea, gas gangrene
Trichinellosis; Roundworm	*Trichinella sprialis*	Parasite	Raw or undercooked pork and wild game, carried in animal feces	Aching joints and muscles, diarrhea, eye swelling, fever, headaches, itchy skin, nausea, vomiting
Tapeworm	*Taenia spp.*	Parasite	Raw or undercooked meat and poultry, carried in animal feces	Abdominal pain, digestive disturbances, intestinal obstruction, weight loss
Acute Hepatitis A	*Hepatitis A Virus (HVA); Taeniasis spp.*	Virus	Contaminated food (esp. shellfish), milk, and water; toxins, drugs, and other diseases	Abdominal pain, flu-like symptoms, itchy skin, loss of appetite, nausea, vomiting, weight loss
Acute Hepatitis E	*Hepatitis E virus (HVE)*	Virus	Contaminated food and water; poor sanitary conditions	Jaundice, anorexia, enlarged liver, abdominal pain, nausea, vomiting, fever

Disease/Illness Name	Pathogen Name	Category	**Food/Water Source**	**Symptoms**
Severe Diarrhea	*Rotavirus; Family Reoviridae*	Virus	Contaminated water and food; carried in animal feces	Abdominal pain, diarrhea, fever, vomiting
Botulism	*Clostridium botulinum*	Toxin (Exotoxin)	Contaminated foods by botulism toxin (esp. canned foods)	Blurred vision, difficulty swallowing, double vision, muscle weakness, slurred speech
Gastroenteritis	*Norovirus; Family Caliciviridae*	Virus	Contaminated food and water, person-to-person transmission	Abdominal cramps, diarrhea, nausea, vomiting
Yersiniosis	*Yersinia pseudotuberculosis; Yersinia enterocolitica*	Bacterium	Contaminated water and food, carried in animal feces	Severe diarrhea, fever, abdominal cramps
Arsenicosis (Arsenic Poisoning)	Arsenic	Contaminant (Heavy Metal)	Drinking arsenic-rich water over a prolonged period of time	Blood diseases, cancers (skin, bladder, kidney, lung), diabetes, high blood pressure, skin discoloration and patches, reproductive disorders
Ascariasis	*Ascaris lumbricoides*	Parasite	Contaminated soil, irrigation with inadequately treated wastewater	Abdominal pain, coughing, difficulty breathing, intestinal blockage, fever, wheezing, worms in feces
Cyanobacteria Intoxication	*Cyanobacteria; Cyanotoxins*	Bacterium	Water containing cyanotoxins	Diarrhea, fever, headache, liver damage, mouth blisters, muscle and joint pain, nausea, skin irritation, sore throat, stomach cramps, vomiting
Fluorosis (Dental and Skeletal)	Fluoride	Halide	Excess fluoride in drinking water	Damage to teeth (short term), severe skeletal problems (long term)
Dracunculiasis (Guinea Worm Disease)	*Dracunculus spp.*	Parasite	Water contaminated by a water flea (*Cyclops spp.*)	Burning sensation, fever, itching, leg blisters, round worm emergence, swelling
Typhoid (Typhoid Fever)	*Salmonella typhi*	Bacterium	Contaminated food or water, food or beverages prepared by an infected person	Anorexia, constipation, diarrhea, enlarged spleen and liver, headache, malaise, rose-colored spots on the chest, sustained fever
Paratyphoid Fever	*Salmonella paratyphi*	Bacterium	N/A	N/A
Avian Influenza (e.g., HPAI)	Avian Influenza A Virus	Virus	Direct or close contact with H5N1-infected poultry or H5N1-contaminated surfaces	60% of those people reported infected with the virus have died.
Variant Creutzfeldt-Jakob disease	Bovine Spongiform Encephalopathy (BSE)	Prion	Contaminated meat and meat products	Rapidly progressive dementia leading to memory loss, personality changes, hallucinations, speech impairment, jerky movements, balance and coordination dysfunction, seizures

Source: Data from World Health Organization (2010) and EuroStat (2007).

World Health Organization (2010) Fact Sheets. Accessed on 12/20/2010 at http://www.who.int/mediacentre/factsheets/en/.
EuroStat (2007) Inventory of Food Safety Diseases: Final Ranking to Identify the "Top 20" Most Important Diseases. Accessed on 12/20/2010 at http://circa.europa.eu/Public/irc/dsis/foodsafetystats/library?l=/documents_statistics/human_health_related/162_health_annex/_EN_1.0_&a=d.

2.3 Chemical contaminants

PLANT TOXINS

Plant toxins are common in some of the world's most important staple and other food crops: cyanide in cassava; tannin, vicine and convicine in faba bean; and phytate and raffinose family oligosaccharides (RFOs) in most of the food legume crops (Table 3). These plant toxins may cause specific diseases when consumed in large quantities over a prolonged period—for example, favism, lathyrism, and konzo. In smaller doses, they are known to impair health through reduced micro-nutrient intake and impacts on immunity and growth in infants and children (Nhassico et al. 2008). While many of these crops are irreplaceable, due to their adaptation to arid and semi-arid environments and nutrient-deficient soils, less toxic cultivars have been identified or developed through breeding programs, and relatively low-cost mitigation strategies can greatly reduce these health hazards.

Table 3—Naturally occurring plant toxins

Disease/Illness	Substance	Category	Sources	Symptoms
Konzo	CH_3CN (cyanide)	Toxin (natural)	Cassava plant	Negative influence on the bioavailability of iron and zinc; spastic paraparesis of the legs
Lathyrism	β-N-oxalyl-L-α, β-diaminopropionic acid (β-ODAP)	Toxin (natural)	Grass pea (found in Ethiopia, India, Nepal, Bangladesh, for example)	Negative influence on the bioavailability of iron and zinc; spastic paraparesis of the legs
Favism	Condensed tannins, vicine, and convicine	Toxin (natural)	Faba bean (found around the Mediterranean, for example)	Negative influence on metabolism of sulphuric amino acids; enzyme deficiency in the blood; results in anemia
Malnutrition	Phytic acid, phytate, and raffinose family oligosaccharides (RFOs)	Toxin (natural)	Many leguminous crops	Negative influence on the bioavailability of iron and zinc
Scombroid [histamine] Poisining	Histamine	Toxin (natural)	Mainly decaying seafood	Skin flushing, headache, oral burning, abdominal cramps, nausea, diarrhea, loss of vision
Red kidney bean poisoning	Lectin	Toxin (natural)	Kidney beans	Headache, abdominal cramps, nausea, diarrhea

Source: Data from World Health Organization 2010, Tshala-Katumbay and Spencer 2007, and Spear and Fehr 2007.
World Health Organization (2010) Fact Sheets. Accessed on 12/20/2010 at http://www.who.int/mediacentre/factsheets/en/.

CHRONIC OR ACUTE EXPOSURE TO PESTICIDES AND OTHER RESIDUES

Intensification of agriculture and monocropping, as well as the increasing markets for perishable foods, have resulted in increased reliance on pesticides, herbicides, and fungicides to maintain productivity and reduce losses, both pre-harvest and post-harvest. The growth of supermarkets and the development of niche markets have bolstered demand for unblemished food products, encouraging farmers to use high levels of pesticides shortly before harvest, to reduce the risks of blemishes that would affect the desirability and therefore the value of their product (Berdegue et al. 2005). In urban areas, the wastewater used to irrigate peri-urban gardens may be severely contaminated with hazardous chemicals. And, while export crops are generally carefully monitored by exporters and regulators for traces of chemical residues, crops destined for domestic consumption are less thoroughly scrutinized.

Exposure to these chemicals is known to lead to birth defects, blindness, blurred vision, cancers, death, flu, headaches, infertility, miscarriage, paralysis, skin rashes, and sterility (Wilson and Otsuki 2004, Thundevil et al. 2008). Table 4 summarizes these hazards. In 1990, the WHO estimated that one million people suffer acute pesticide poisoning each year, and the majority of these cases are from low- and middle-income countries (Jeyeratnum 1990). Consumption of trace chemical residues is generally associated with chronic health effects that are less visible and thus difficult to quantify; there are no precise estimates of chronic health impacts of long-term low-level exposure to pesticides (Konradson 2007). Exposure to pesticides is exacerbated by inadequate safety precautions, inadequate information provided to users, and inadequate implementation of regulations controlling their sale and use (ILO 2000).

Table 4—Select pesticides and associated health impacts

Pesticide Class	Common Examples	Category	Symptoms
Arsenicals	Arsenic trioxide, CCA, sodium arsenate	Toxin (chemical)	Abdominal pain, nausea, vomiting, garlic odor, metallic taste, bloody diarrhea, headache, dizziness, drowsiness, weakness, lethargy, delirium, shock, kidney insufficiency, neuropathy
Borates (insecticide)	Boric acid, borax	Toxin (chemical)	Upper airway irritation, abdominal pain, nausea, vomiting, diarrhea, headache, lethargy, tremors, kidney insufficiency
Carbamates (insecticide)	Carbaryl, thiram, aldicarb, mecarbam	Toxin (chemical)	Malaise, weakness, dizziness, sweating, headache, salivation, nausea, vomiting, diarrhea, abdominal pain, confusion, dyspnea, dermatitis, pulmonary edema
Chlorphenoxy compounds (herbicides)	Di/tri- chlorophenoxy-acetic acid, MCPP	Toxin (chemical)	Upper airway and mucous membrane irritation, abdominal pain vomiting, diarrhea, tachycardia, weakness, muscle spasm, coma, acidosis, hypotension, ataxia, hypertonia, seizures, dermal irritation, headache, confusion, acidosis, tachycardia
Calciferol (rodenticide)	Cholecalciferol, ergocalciferol	Toxin (chemical)	Fatigue, anorexia, weakness, headache, nausea, polyuria, polydipsia, renal injury, hypocalcaemia
Chloralose	Chloralose	Toxin (chemical)	Vomiting, vertigo, tremor, myoclonus, fasciculation, confusion, convulsions
Copper compounds (fungicide)	Copper acetate, copper oleate	Toxin (chemical)	Abdominal pain, vomiting, skin/airway/mucous membrane irritation, renal dysfunction, coma
Coumarins (rodenticide)	Brodifacoum, warfarin, pindone	Toxin (chemical)	Echymoses, epistaxis, excessive bleeding, haematuria, prolonged prothrombin time, intracranial bleed, anemia, fatigue, dyspnea
Diethyltoluamide (insect repellent)	DEET (N,N-diethyl-meta-toluamide)	Toxin (chemical)	Dermatitis, ocular irritation, headache, restlessness, ataxia, confusion, seizures, urticaria
Dipyridil (herbicide)	Paraquat, diquat	Toxin (chemical)	Mucous membrane and airway irritation, abdominal pain, diarrhea, vomiting, gastrointestinal bleeding, pulmonary edema, dermatitis, renal and hepatic damage, coma, seizures
Phosphonates (herbicide)	Roundup, glyphosate	Toxin (chemical)	Airway, skin, and mucous membrane irritation, abdominal, pain, nausea, vomiting, shock, dyspnea, respiratory failure
Fluoroacetate (rodenticide)	Sodium fluoroacetate	Toxin (chemical)	Vomiting, paresthesias, tremors, seizures, hallucinations, coma, confusion, arrhythmias, hypertension, cardiac failure
Mercury, organic (fungicide)	Methyl mercury	Toxin (chemical)	Metallic taste, paresthesias, tremor, headache, weakness, delirium, ataxia, visual changes, dermatitis, renal dysfunction
Metal phosphides(rodenticide, fumigant)	Zinc-, aluminium-, magnesium-phosphide	Toxin (chemical)	Abdominal pain, diarrhea, acidosis, shock, jaundice, paresthesias, ataxia, tremors, coma, pulmonary edema, tetany, dermal irritation
Halocarbons (fumigant)	Cellfume, Methyl bromide	Toxin (chemical)	Skin/airway/mucous membrane irritant, cough, renal dysfunction, confusion, seizures, coma, pulmonary edema
Nitrophenolic and nitrocresolic herbicides	Dinitrophenol, dinitrocresol, dinoseb, dinosarn	Toxin (chemical)	Sweating, fever, confusion, malaise, restlessness, tachycardia, yellow skin staining, seizures, coma, renal insufficiency, hepatic damage
Organochlorines (insecticide)	Aldrin, dieldrin HCB, endrin, lindane	Toxin (chemical)	Cyanosis, excitability, dizziness, headache, restlessness, tremors, convulsions, coma, paresthesias, nausea, vomiting, confusion, tremor, cardiac arrhythmias, acidosis
Organophosphates (insecticides)	Malathion, para-thion, dichlorvos, chlorpyrifos	Toxin (chemical)	Headache, dizziness, bradycardia, weakness, anxiety, excessive sweating, fasciculation, vomiting, diarrhoea, abdominal cramps, dyspnea, miosis, paralysis, salivation, tearing, ataxia, pulmonary edema, confusion, acetylcholinesterase inhibition
Organotin (fungicide)	Fentin acetate, fentin chloride	Toxin (chemical)	Airway, skin, and mucous membrane irritation, dermatitis, salivation, delirium, headache, vomiting, dizziness
Phenol derivatives (fungicide, wood preservative)	Pentachlorophenol, dinitrophenol	Toxin (chemical)	Skin, airway, and mucous membrane irritation, contact dermatitis, dyspnea, diaphoreses, urticaria, tachycardia, headache, abdominal pain, fever, tremor
Pyrethrins, pyrethroids	Allethrin, cyfluthrin, permethrin	Toxin (chemical)	Allergic reactions, anaphylaxis, dermatitis, paresthesias, wheezing, seizures, coma, pulmonary edema, diarrhea, abdominal pain
Strychnine (rodenticide)	Strychnine	Toxin (chemical)	Muscle rigidity, opisthotonus, rhabdomyolysis
Thallium (rodenticide)	Thallium sulfate	Toxin (chemical)	Abdominal pain, nausea, vomiting, bloody diarrhea, headache, weak-ness, liver injury, hair loss, paresthesias, neuropathy, encephalopathy, cardiac failure
Triazines (herbicide)	Atrazine, prometryn	Toxin (chemical)	Mucous membrane, ocular and dermal irritation

Source: Data from Thundiyil et al. (2008)

MYCOTOXINS

Mycotoxins are toxic by-products of fungi commonly found in tropical environments worldwide; they are thought to affect 25 percent of the world's food crops. Among the most common mycotoxins are aflatoxins, fuminosins, trichothcenes zearalenone, and ochratoxin A. The spores of fungi known to produce mycotoxins are commonly found in soils, and contamination may take place both pre- and post-harvest. Conditions for fungal growth and production of mycotoxins are moist, humid conditions, exacerbated by damage due to pests or mechanical damage. Crops are particularly susceptible to pre-harvest contamination when stressed, for example due to drought, especially during flowering.

Aflatoxin, an odorless and tasteless by-product of a common fungus (*Aspergillus spp*.), has been classified by the WHO as a Class A carcinogen, and the EU maximum residue limit is just 4 parts per billion (ppb). Aflatoxin is associated with increased risk of liver cancer in humans, particularly among people infected with the Hepatitis B virus, and there is evidence that chronic exposure can lead to stunting in children and immunodeficiency (Williams et al. 2004; Gong et al. 2003, 2004). In Mali, for example, aflatoxin contamination is persistent in groundnuts grown as a cash crop and for local human and livestock consumption, and there is growing concern regarding the long-term health risks of exposure among children whose health is already compromised by one of the world's highest rates of malnutrition (UNICEF 2009). Acute exposure to aflatoxin can cause aflatoxicosis which can be highly fatal, particularly among children; in Kenya in 2004, 125 people died due to acute exposure to aflatoxins. Among livestock, aflatoxins are known to cause retardation in growth and productivity, and they are highly toxic to poultry. Similarly, a recent study from Tanzania found that exposure to fumonisin in maize flour had significant impact on growth of infants less than 12 months (Kimanya et al. 2010). Table 5 summarizes the major health threats posed by mycotoxins.

Table 5—Select environmental chemical contaminants and their health implications

Disease/ Illness Name	Chemical contaminant	Category	Food/Water Source	Symptoms
Lead poisoning	Lead	Contaminant (heavy metal)	Exposure to lead	Abdominal pain, headache, anemia, irritability, and in severe cases seizures, coma, and death
Mercury poisoning	Mercury	Contaminant (heavy metal)	Exposure to mercury	Toxic effects include damage to the brain, kidney, and lungs. Can result in several diseases, including Hunter-Russell syndrome and Minamata disease
Cadmium poisoning	Cadmium	Contaminant (heavy metal)	Exposure to cadmium	Flu-like symptoms including chills, fever, and muscle ache. More severe exposure can cause tracheo-bronchitis, pneumonitis, and pulmonary edema
Mycotoxin: Aflatoxicosis	Aflatoxin; Aspergillus spp.	Toxin (fungal)	Contaminated staple foods such as cereal crops, nuts, pulses, and coconut	Death, cancers (esp. liver), gastrointestinal hemorrhage, growth retardation, immune suppression, jaundice, edema
Mycotoxin: *Ochratoxin* Intoxication	*Ochratoxin; Aspergillus spp.* and *Penicillin spp.*	Toxin (fungal)	Contaminated cereal crops, coffee, dried fruit, red wine	Cancers, immune suppression, kidney failure
Mycotoxin: *Fumonisin* Intoxication	Fumonisin; Fusarium spp.	Toxin (fungal)	Contaminated cereal crops (esp. pre-harvest)	Abdominal pain, diarrhea, fever, gastrointes-tinal ulceration, vomiting

Source: Data from World Health Organization 2010 and EuroStat 2007.

2.4 Occupational Health

The agricultural sector is one of the most hazardous sectors worldwide (Loureiro 2009). Human health risks associated with agriculture include: exposure to weather (in particular, health risks related to prolonged and repeated dehydration); close contact with animals (and associated exposure to zoonotic pathogens); chronic exposure to pesticides, herbicides, and other chemical and biological products; long hours; and risks associated with the use of hazardous agricultural tools and machinery (Cole 2006). Occupational hazards may pose health risks along the length of the value chain, including food handling and processing (through exposure to chemicals and machinery).

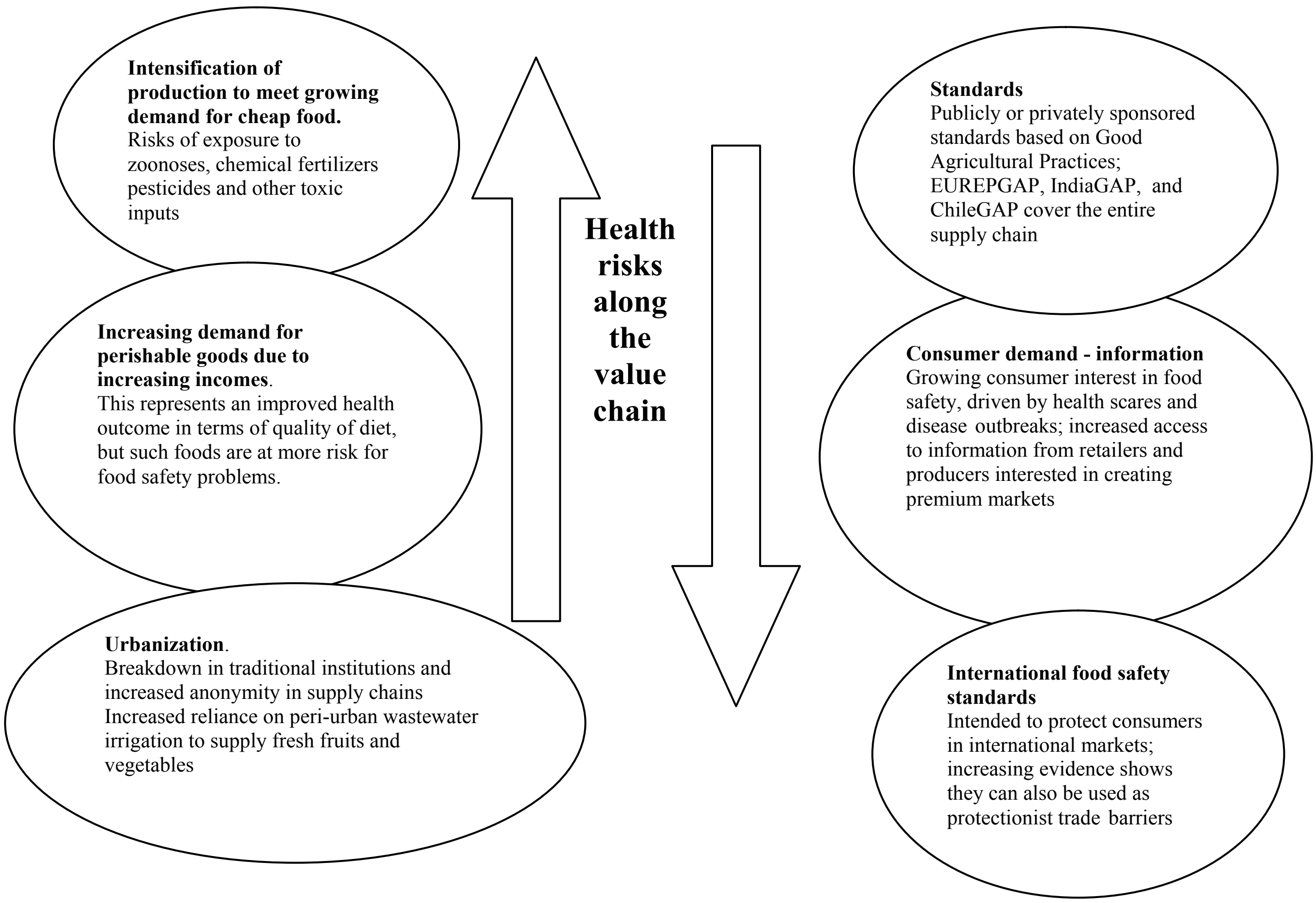
Cole (2006) estimates that 2 to 5 million people annually suffer acute poisoning from exposure to fertilizers, pesticides, herbicides, and other chemical inputs, including 40,000 deaths every year; there are additionally

170,000 fatal injuries annually in agriculture. In LDCs, where the share of labor employed in agriculture is relatively high and the enforcement of health and safety regulations is weak, the situation is especially critical. Agricultural employment accounts for 63 percent of the workforce in Africa and 62 percent in Asia, compared to only 5.2 percent in the European Union and 3 percent in the United States. Women are an important part of this workforce, and where protective clothing or other measures are not employed, they and their children are particularly vulnerable to chemical hazards during pregnancy and lactation.

3. Drivers of Change Affecting Food Safety

Figure 2 illustrates the factors that are driving changes in health risks along the value chain. These factors may increase or decrease health risks, and their impacts may be differentially felt by different populations.

Figure 2—Drivers of change along the value chain



Chapter 1 described a number of factors that are driving increasing health risks along the value chain:

- Changes in consumption patterns towards perishable and processed foods that are at higher risk of contamination
- Increasing demand for cheap foods to address food insecurity for a growing global population, leading to health risks related to intensification of production (including increasing dependency on chemical inputs), as well as increasing risks of zoonoses and emerging zoonotic diseases and pandemics such as Swine Flu
- Increasing urbanization that leads to greater anonymity along the value chain and fewer incentives for individuals actors to invest in food safety, as well as increasing problems of contamination associated with wastewater irrigation

There are also a number of factors that drive processes to reduce health risk along the value chain, including consumer demand, international standards, and improved monitoring technology.

3.1 Consumer demand and willingness to pay for safer foods and reduced risks

As income increases, so does the demand for safer and higher quality food, and willingness to pay more for safer food. In developed countries, consumer demand for high-quality and safe food has been driven by several factors: increased awareness of food safety; education regarding links between diet, nutrition, and health; consumer awareness of quality characteristics; and access to information about new production and processing technologies.

Several studies in developed countries (Australia, Canada, France, Finland, Germany, Greece, Italy, Norway, Sweden, U.K., and U.S.) find that consumers demand food safety and that they are willing to pay price premiums for safer food (Table 6). A wide array of food safety risks are investigated in these studies, such as BSE, growth hormones, and general health risks from food-borne illnesses, and chemical use. Some studies also investigate consumers' willingness to pay (WTP) for various food certification/labeling programs, such as those for safety inspections and traceability. These studies examine demand for a variety of food products, including meat (poultry, beef, sausages), eggs, milk, olive oil, fruits and vegetables, grains, bread, and wine. Various stated and revealed preference methods are used, such as the choice experiment method, contingent valuation method, and hedonic pricing method (see Lusk et al. 2003; Enneking 2004; Carlsson et al. 2005; Canavari et al. 2005; Rigby and Burton 2005; Loureiro and Umberger 2004; Goldberg and Roosen 2007; Annett et al. 2008). In general, the findings reveal that, in developed countries, consumer willingness to pay higher prices for safer food varies depending on several factors, including consumers' income and food safety awareness levels.

A limited number of studies investigate consumers' valuation of safer food and water in LDCs; they generally conclude that price premiums are associated with information, and especially an understanding of potential health risks (Roy et al. 2010). A recent study comparing estimated consumer preferences for reduced pesticide residues in onions in developed countries (France and U.S.) and developing countries (China and Niger) found that Chinese consumers are willing to pay a price premium as high as US$0.80 per pound of onions produced without pesticides. In Niger, however, consumers are willing to pay US$0.90 for onions produced *with* pesticides, as they believed farmers would benefit from increased pesticide applications by gaining higher yields; it is unclear whether consumers had information regarding product safety. (Ehmke et al. 2008). Probst et al. (2010) investigate consumer attitudes toward and markets for organically produced vegetables in Ghana, and find that consumers believe that food has a higher health value if it is fresh-looking (free from damage and insects, not "dirty"). The study reports that wealthy consumers indicated they would be prepared to buy a certified "pesticide-free" vegetable even if the product was more expensive, or only available in another part of the city, or was smaller; but 90 percent of respondents would not buy it if it appeared slightly damaged compared to a conventional product. Such consumer preferences for visible "quality" attributes create a "pull-effect" on pesticide use, encouraging farmers to apply pesticides on vegetables shortly before harvest to prevent blemishes.

These studies in developing countries have primarily used hypothetical experiments. While some studies suggest that consumers in developing countries are willing to pay for safety attributes, their ability to pay, at least among the poorest, remains low, and the market demand for safe products remains unproven (Delgado 2005).

3.2 Modern value chains and the demand for safe foods

The phenomenon of the super market or hypermarket in developing countries and the impact it is having for farming practices and livelihoods across the world has a growing literature associated with it. Today, supermarkets are increasingly a feature in developing countries, not just in larger urban cities but also in regional and smaller towns. Multinational corporations such as Walmart and Carrefour are increasingly important players. By 2005, 40 percent of Chile's smaller towns had supermarkets, as did many small- to medium-sized towns in low-income countries such as Kenya; in Mexico, an estimated 30 percent of expenditures on food was spent in Walmart in 2003. (Reardon et al. 2003). While supermarket are undoubtedly spreading, their importance still varies considerably and they only reach a minority of consumers in many developing countries. In Taiwan in 2000, over 60 percent of food sales were in the modern retail sector, as compared to just 20 percent in Malaysia (Cadilhon et al. 2006).

Supermarkets and modern value chains are playing a fundamental role in restructuring the entire food supply chain, with increasing use of consolidating centers, a focus on efficiency and cost saving, and a highly competitive environment in which supermarkets must balance high quality and low cost to meet the demands of the urban consumer. Large-scale supermarket and other agrifood industries, particularly those involving multinationals, have both the incentive and capacity to impose private standards (Balsevich et al.

Table 6—Examples of consumers' willingness to pay (WTP) for food safety attributes

Authors (year)	Foodstuff Valued	Country	Food safety or food hazard attributes	WTP Estimates
Lusk, Roosen, and Fox (2003)	Beef	France, Germany, UK, and US	Cattle growth hormones	$9.94 in France, $7.29 in Germany, $7.39 in UK and $8.12 in US for beef from cattle not administered growth hormones
Enneking (2004)	Sausages	Germany	Quality and safety (Q&S) label	$0.34 for Q&S label attached to a national premium brand; $0.11 for Q&S label attached to a national brand with low degree of brand awareness
Latvala and Kola (2004)	Beef	Finland	Safety and traceability	€2-16/kg of beef that is safe and traceable
Loureiro and Umberger (2004)	Steak	US	Food safety inspection label and traceability label	$3.894/lb of steak with food safety certification and $1.031 for traceability label
Canavari, Nocella, and Scarpa (2005)	Apples and peaches	Italy	Pesticide ban	€62.76 per year for pesticide ban (82.2% of consumers)
Carlsson, Frykblom, and Lagerkvist (2005)	Grain	Sweden	Spraying and cadmium	6.8 SEK/2kg of grain for restrictive use of spraying; 5.5 SEK/2kg of grain for soil and grain analyzed for cadmium
Goldberg and Roosen (2005)	Chicken breast	Germany	Health risk reduction of Campylobacteriosis (CS) and Salmonellosis (SS)	€ 2.375/kg of chicken for 80% reduction of CS risk and 80% reduction of SS risk.
Rigby and Burton (2005)	Food production system	England	Farm chemical use and food health risk	11.7-60.2 % increase in the food bill for a 10% reduction in chemical use; 21.9-36.3 % increase in the food bill for a reduction in food health risk from 1/10000 to1/15000

Source: Narrod et al., 2009

2003); this trend has major impacts on producers and traders, by increasing demand for high-quality, safer food.

Four main factors are driving the imposition of private standards by international and multinational food processing and retail industries (adapted from Reardon et al. 2009):

1. To substitute for missing or inadequate public standards, particularly as global companies may risk their international reputations (or even face criminal liability for lack of due diligence).
2. To compete with traditional retail markets, particularly with respect to perishable fresh goods.
3. To differentiate their products and create competitive advantage over other suppliers and retailers.
4. To provide an incentive to producers to improve quality.

The costs associated with developing, implementing, and monitoring such standards are only justified when the consumer is made aware of the standards. This creates an incentive for retailers and others to inform consumers of the health advantages of safe food. Such mechanisms do not rely on government to provide certification, although governments have a role in providing oversight to any systems of standards. Studies have demonstrated the effectiveness of certification and provision of information in creating demand for safe produce (Birol et al. 2010). However, this may not result in an increase in price for certified safe products, but rather to a decline in the price customers are willing to pay for food that is not certified or considered safe (Rozan et al. 2004).

Overall, the shift towards highly competitive multinational companies dominating the marketplace has tended to drive down the prices paid to suppliers, thus burdening small-scale farmers in particular with the additional (fixed) costs of improved production (Reardon et al. 2009). However, a few interesting exceptions provide useful clues for designing pro-poor safe food production; these are discussed in Chapter 5.

It is important to note that, while multinationals play an ever-increasing role in agribusiness in developing countries, the majority of consumers, particularly in rural areas, still rely on traditional market outlets, and they will continue to do so as long as they lack refrigeration for fresh foods such as meat, dairy, and vegetables (Cadilhon et al. 2006). For example, in Vietnam, although modern marketing channels may be more efficient than traditional ones, fruits, vegetables, meat and fish markets are still dominated by traditional markets and itinerant retailers.

3.3 INTERNATIONAL STANDARDS AND TRADE RESTRICTIONS

International food safety standards might be thought purely a public good, as a driver and mechanism to regulate for food safety and protect the health of the importing population. However, these regulations have varying implications for different exporting countries, including the potential for creating trade barriers, owing to several factors.

The science defining the effect of different levels of food safety on human and/or livestock health is usually not clear or definitive, making it difficult to draw a line between food safety regulation and unwarranted trade restriction. In many cases, health impacts are only known at a broad level. For example mycotoxins are known to be highly carcinogenic and harmful to humans and animals—but science is lacking on whether the maximum residue limit should be set at 4 parts per billion (ppb) as imposed in Europe or 20 ppb as imposed in the US. Such ambiguities can result in trade disputes. In their analysis of impacts of sanitary and phytosanitary (SPS) and technical barriers to trade (TBT) regulations on worldwide imports and exports of select agricultural commodities, Disdier et al. (2008) conclude such regulations have a negative trade impact on developing countries while offering de facto protection to competing import firms.

Even when science is clear, the risk preferences and perceptions of risk could differ across countries. Countries (and populations within countries) can differ in their preferences for risk-risk tradeoffs, and thus may rightfully demand different levels of expected health. As a result, levels of regulation may vary across countries. This problem is compounded by the fact that the aim to protect health is often bundled with other objectives. An example is trade policies in Europe relating to Genetically Modified Food (GMFs): part of the restrictions can be attributed to Europeans' subjective assessment of health consequences from GMF consumption, and part to non-health objectives related to environment.

The multilateral or international mandate for regulation of food safety standards intended to protect health is limited. Under Article 20 of the World Trade Organization (WTO), all countries have sovereignty to set their own SPS standards, as long as they implement them in a non-discriminatory fashion and have reasonable scientific basis. This, in effect, puts some limits (ostensibly weak) on the ability of countries to implement their own standards. However, food standards have increasingly been taken over by private entities or groups of retailers. Currently, in addition to the various international food safety standards (such as CODEX and ISO Series[5]) and the national and supra-national standards, there are also private standards (such as GlobalGAP[6] and various developed-country supermarket standards) (Okello et al. 2007). For example, the U.K. supermarket chain TESCO has branded "nature's choice," a standard that all its suppliers of fresh fruits, vegetables, and salads must meet. The multiplicity and dynamic nature of these ever-changing standards can act as barriers to trade, particularly for developing countries' agricultural exports. The fact that standards imposed by importing countries can be challenged in the WTO, under its dispute settlement mechanism, implies that they have important bearing on the international mandate of non-discriminatory behavior.

A given level of regulation implies different constraints for different exporting countries and exporters. Regulations to protect health impose costs on producers—most importantly, fixed costs, which create variable impact by size of producer. Hence, small farmers tend to face, *de facto*, a greater barrier in meeting the same regulation.

At an institutional level, there might be constraints on the capacity of developing countries to participate in the formulation of international regulations, as well as to implement or challenge implementation of regulations. Athukorala and Jayasuriya (2004) suggest that, though the SPS Agreement proves a useful mechanism to ensure that SPS measures are not abused or misused, in practice developing countries were often placed at a disadvantage, hampered by limited capacity to access and absorb best practice technology and information,

[5] CODEX develops food standards, guidelines, and related texts such as codes of hygienic practice, principles for inspection, and certification for food imports under the Joint FAO/WHO Food Standards Program. Office International des Épizooties deals with issues pertaining to animal health, while the International Plant Protection Convention (IPPC) is recognized as a source of standards, guidelines, and recommendations relating to plant health. The standards, guidelines, and recommendations developed by CODEX, OIÉ, and IPPC reflect international scientific consensus on good risk management and appropriate hazard tolerance levels (Lupien 2000; Unnevehr 2000; Narrod et al. 2002).

[6] The GlobalGAP (formerly EurepGAP) standard was initiated by retailers cooperating in the Euro-Retailer Produce Working Group (EUREP), with the aim of creating a common standard as a farm management system for good agricultural practices (GAP).

and lacking resources to challenge perceived inequities. A country where domestic labs are unable to reliably test samples or are not accredited, and where there are few certifiers and auditors, will have a bigger gap to bridge in terms of assured compliance, so that certification may have to be obtained from outside agencies at increased cost.

Both fixed and variable costs will vary depending upon the gap that needs to be bridged for a producer to reach compliance, again implying differential impact across countries and exporters. For example, a producer who lacks access to clean water for irrigation will require a far greater investment than a producer with cheap access to uncontaminated water sources.

The existing literature presents wide-ranging evidence of the inability of smallholders to meet market requirements for food safety in high-value markets (Reardon and Berdegué 2002; Ghezan et al. 2002). As a result of these stringent food safety standards, poor producers in developing countries often lose their comparative advantage in the international markets and cannot access lucrative export markets (World Bank 2005). There is a need to research how to build the institutional and technical capacities of small-scale producers as well as policymakers, to ensure developing-country producers' access to international markets.

Health is a credence attribute in food and hence reputation and credibility are extremely important especially in international trade. Health or food safety attribute in food is a credence characteristic; that is, the utility from consumption can be ascertained only long after consumption. In such products, problems of adverse selection can be minimized only by assessing the reputation of the seller, through credible certification. Food safety failures are more common in developing countries, and such a reputation is presumably more difficult to achieve. Under asymmetric information, reputation is determined by the average performance on food safety, which tends to be lower in developing countries.

There have been continual disputes over the use and the inequitable effects of sanitary and phytosanitary (SPS) and technical barriers to trade (TBTs), as nontariff trade restrictions. By 2000, about a third of the cases considered by the WTO dispute settlement panel had reference to the SPS or TBT agreement (Maskus and Wilson 2001). Josling et al. (2004) calculate that, between 1995 and 2001, most of the complaints in the SPS Committee of the WTO were filed by developed countries (109 out of a total of 187), nearly half of which were against developing countries—even though the volume of North-North trade dwarfs that of North-South trade.

In analyzing the trade impacts of food safety regulations, three main points should be kept in mind, points that have largely been ignored in the literature.

1. **International sanitary and phytosanitary standards can be significant trade barriers, particularly for an industry dominated by small-size producers, when compliance involves fixed costs.** Unlike tariffs, these standards serve a legitimate function even for a small open economy, to protect human, animal, and plant health. However, the true loss from protective standards is higher than the simple deadweight losses, as in case of tariffs: even small increases in fixed costs may shift smaller firms or farms out of the export market altogether, and this lost trade is not captured in statistical measures (see Box 1). Hence, unless the health benefits from regulation are significant, the real costs may well outweigh the benefits.

2. **These regulations increase the risks to exporters, since they tend to be stringent (with little margin of error) and dynamic.** Thus, after costs for exporting have been incurred, exportables may still be rejected and denied entry. Bridging the regulatory gap between exporting and importing countries could have significant benefits in terms of mitigating such risks in exporting, by decreasing the likelihood that products will be rejected. Upgrading domestic standards and creating a domestic demand for health regulation and food safety could form part of a broader export promotion strategy by providing a cushion against export shocks.

3. **The trade restrictiveness of a specific health regulation is best assessed in terms of the regulatory and health gaps that each country (or producer) must bridge to achieve market access.** From a development perspective, this implies that the focus should be on building or strengthening capacity to meet the standards set by regulations, instead of trying to change those regulations.

Box 1—Mycotoxins regulations and trade flows

Little empirical research exists on the effect of food safety regulations on international trade flows. One study explores the trade effect of the European Commission (EC) proposal to harmonize aflatoxin standards (announced in 1998 and implemented in 2002) (Otsuki et al. 2001a). The study predicted the trade effect under three regulatory scenarios: standards set at pre-EU harmonized levels (status quo); the harmonized EU standard adopted across Europe in 2002; and a standard set by the Codex Alimentarius Commission. On the basis of existing trade, the authors estimated effects on African exports at the level of US$670 million. However, this *ex ante* assessment has not been validated by ex post trade data, showing very little or no effect. A similar analysis for groundnuts projected trade losses at US$450 million (Otsuki et al. 2001b).

Diaz Rios and Jaffee (2008) argue that Otsuki et al. overestimate the effects of the regulation of African groundnut exports, conflating secular declines in groundnut exports with the effect of mycotoxins regulation. Since the large effects that are predicted by Otsuki et al. have not been observed, this leads to the question of the reasons for over-estimation of the effects. Two main reasons account for overestimation. First, trade costs were measured bilaterally (such as distance between exporter and importer) as opposed to the multilateral approach, shown to be the correct method by Anderson and van Wincoop (2003). Second, the study ignored zero trade among countries (Melitz 2003).

Munasib and Roy (2010) adopt a framework that corrects for these two issues. The imposition of mycotoxin regulations not only reduces the volume of existing trade but it also shifts producers out of export markets With extra costs of meeting the tighter regulations many producers do not find it worthwhile to export to certain markets. Consequently, regulations result in “lost trade” (that is, trade that never appears in the data) that needs to be taken into account. The authors find significant correlation between relative levels of aflatoxins regulations and relative volume of trade flows in the case of groundnuts, though such evidence is much weaker for trade in maize. They argue that the real effect of a tighter standard is market reallocation toward markets with lighter standards.

Simulating hypothetical changes in groundnut regulations, Munasib and Roy (2010) show the effect when one country moves to a tighter standard. For the biggest percentage change in relative regulation (moving from a limit of 15 to 2 parts per billion), the exports of groundnuts to lower standard markets will increase by 22.5 percent. Moving from the Codex standard to the harmonized EU standard will raise the exports to lower standard markets by 13.5 percent. No significant effect is found in case of maize trade, although more analysis is needed to account for the food-feed distinction in maize trade.

3.4 ADVANCES IN DETECTION METHODS – INSTITUTIONAL CAPACITY AND COSTS OF DIAGNOSTICS

As demand for safe food increases, so does the need for effective low-cost technology and institutional and technical capacity to monitor and regulate health risks along the value chain. Increasing concerns about food safety have fostered research into quicker and more cost-effective methods of detecting and tackling food safety risks.

- DNA “fingerprinting” is used by pulsed-field gel electrophoresis (PFGE) on disease-causing bacteria isolated from humans or from suspected food, using standardized equipment and methods to quickly identify the source of outbreaks.
- Nanotechnology is used to test for BSE in cattle and scrapie in sheep, as well as to detect bacterial pathogens in other foodstuff.
- Various advances have been made in microbiological analysis, sampling and testing.

A wide range of detection techniques are currently available, in addition to traditional culture methods: electrical methods, ATP bioluminescence, microscopy techniques, the wide range of immunological methods such as ELISAs, genetic techniques, and the use of biosensors and applied systematic techniques (McMeekin 2003). There now exists laser technology that can detect and identify many types of bacteria about three times faster and at one-tenth the cost of the traditional culture method. In addition, chlorine gas has been found effective for killing pathogens on fresh produce (fruits and vegetables). However, developing country food producers, processors, and consumers rarely have access to or knowledge of these technologies. In any case, they may be reluctant to adopt new technologies without evidence of their costs, benefits, and effectiveness.

Advances in nanoscale sciences may present a new opportunity to help improve the livelihood of the poor. Of particular importance to developing countries are the nanotechnology applications addressing low-use efficiency of inputs (nutrients, irrigation water, and pesticides) under conditions of stress such as drought and high soil temperature (Lal 2007).

Spoilage of food and the incorporation of toxic substances are problems throughout the world, but perhaps especially detrimental to developing countries with poor cold-storage facilities (Gruère, et al. 2010). Salamanca-Buentello et al. (2005) identify several nanotechnology applications for food safety and nutrition that experts expect to be available for developing countries within the next 10 years. These include nanocomposites for plastic film coatings used in food packaging; antimicrobial nanoemulsions for applications in decontamination of food equipment, packaging, or food; nanotechnology-based antigen-detecting biosensors, for identifying pathogen contamination; nanosensors for pest detection; and nanoparticles for new pesticides, insecticides, and insect repellents.

4. Challenges to the Poor in the Face of Increased Health Risks Along the Value Chain

Food and water safety affect the livelihoods of poor producers and consumers through two major channels: health and market access.[7] Much of the debate on food safety has focused on developed countries, reflecting an assumption that food safety is a luxury—and hence a concern only for the wealthy. In fact, the exposure to unsafe food and water has greatest impacts on the poor, in relation to livelihoods, health, and nutrition.

Effective demand for food safety, however, typically materializes only at higher income levels. Delgado (2005) suggests that only when their income increases to above US$10 a day can consumers begin to afford certain food safety attributes. Presently, 80 percent of the world's population earns less than $10 a day, and 1.4 billion people in the developing world (one in four) are living on less than US$1.25 a day (Ravallion et al. 2009). It may take a long time for most people to reach this affordability threshold, especially if they are trapped in the poverty cycle. And even if incomes rise to this level, many developing country consumers are unaware of the health risks associated with unsafe food and water. They are thus not only unaware of protective measures they could take, but also unwilling to pay a premium for safer food, which could in turn motivate producers to implement food safety risk-reducing practices.

Furthermore, significant market and government failures also reduce the degree to which processes to improve food safety and reduce health risks reach the poor. Most significantly, information problems can bar entry for the poor, while the entry barriers created by fixed costs result in market failures for small-scale producers.

4.1 Problems facing producers

THE COSTS OF COMPLIANCE

Safe food costs money to produce, process, and deliver. Most of the research on the impact of increased concerns of food and water safety on domestic food safety standards has focused on in the experience of developed countries; and much of the research on costs of compliance in developing countries has been descriptive rather than quantitative. Currently there is relatively limited knowledge of the impact of such concerns in less developed countries, where cost impacts will be of particular relevance. In particular, relatively little research has been directed to understanding the impact of increased sanitary and phytosanitary regulation and control (SPS) on livelihoods of the poor, even though increased health and food safety regulation tend to impose costs on producers asymmetrically, with particularly severe impact on the poor in the LDCs.

Table 7 summarizes the literature. Most of the costs of compliance studies are largely descriptive, looking at the costs of compliance at the national level, often in relation to publicly mandated standards. However, as Henson and Reardon (2005) point out, agrifood systems are increasingly adopting private safety and food quality standards that operate alongside the regulatory systems and are equally binding on the suppliers.

Niang (2005) studies the costs of compliance with export standards in the Senegalese fisheries industry. Manarungsan et al. (2005) study the costs of compliance with SPS standards for several exports of Thailand, including shrimp, fresh asparagus, and frozen green beans. Cato et al. (2005) examine costs of compliance for Nicaragua's shrimp sector. Other studies on costs of compliance that follow SPS measures in trade are Pratt et

[7] Often food safety issues are combined with food quality issues, such as nutritional values of food. Some aspects of food quality are also included in this theme as long as they are based on common sets of principles (for example, the effect of information or higher incomes).

al. (2005), for the livestock markets in Ethiopia, and Rich (2005), for foot and mouth disease in the Southern Cone of South America.

These studies focus on aggregate measures of costs of compliance, even though the compliance affects different markets and different products and varies across producers. Nevertheless, certain unifying themes emerge.

1. **The direct costs of compliance at an aggregate level for the developing countries are substantial, in relation to the value of their exports.** For example, the total cost of compliance with the first round of vaccination introduced by the government to check foot and mouth disease (FMD) in Argentina was $65.4 million in 2001 and $17.8 million in 2002 (24 percent of the total export value in 2001, and 3.7 percent in 2002) (Rich 2003).[8] Related costs, such as costs for veterinary services, are unknown but probably substantial. Logistical costs of delivering vaccines can be very high: for the much smaller Uruguay outbreak in 2001 it was $1 million, while the total estimated direct costs were $13.6 million (Casas Olascoaga 2003). On the other hand, in Nicaragua, the total cost to implement shrimp safety and quality standards and hazard analysis and critical control points (HACCP) from 1997 to 2002 ranged from just 0.88 percent to 1.30 percent of the average annual value of shrimp exports, much less than the livestock vaccine programs.
2. **At the disaggregated level, costs of compliance vary by size and by institutional framework.** While there is a clear basis for distinction in the costs of compliance across producers, especially in relation to size (based on human capital and other productive assets), there has been no systematic analysis of the cost differentials between large and small producers or firms. Manarungsan et al. (2005) show that in Thailand, because of food safety requirements, suppliers are making large capital investments to move towards greater integration in value-chain management, which many small farmers cannot afford. However, their study overlooks three critical components of the cost estimates: differentiation of the costs of compliance across farms and analysis of the cost differential based on farm and farmer characteristics; the opportunity costs of capital used in compliance, which tends to vary significantly across farms; and the variation in costs of compliance measures themselves. There is a need to research the cost-effectiveness of the measures employed and the role of institutional support to facilitate effective compliance.

There have been a few attempts to summarize the variation across farmers and across organizational structures: Avendano et al. (2007) for cantaloupe; Okello et al. (2007) for Kenyan green beans; and Calvin et al. for raspberries in Guatemala. Rigorous empirical research on these issues is severely lacking, however. Moreover, very few studies have looked at the long-term impact of the SPS trade-limiting effects or their differential impact on various actors within the value chain, especially poor actors.

Since these studies do not capture the variation across producers or institutional arrangements, they do not provide a basis for evaluating farmer-specific institutional solutions for minimizing the burden of costs of compliance. If costs of compliance involve large fixed costs, can collective action help small farmers? What kinds of information channels are cost-effective in transmitting knowledge about standards? And how are the costs of compliance related to monitoring and technical assistance provided under out-grower programs? These research questions have direct policy relevance, but unfortunately they remain largely unanswered.

[8] These percentages vary widely both because of the recovery of the export market and because of the lower level of vaccination requirements over time, as producers themselves do subsequent vaccination.

Table 7—Examples of research on costs of compliance

Authors (year)	Foodstuff Valued	Country	Food safety attributes	Cost of Compliance Estimates
J. C. Cato, W. S. Otwell, and A. S. Coze (2005)	Shrimp	Nicaragua	Maintaining HACCP and other standards (in transport, freezing, laboratory costs, etc.)	Estimated costs of processing plants to adapt standards and HACCP program (US$; three processing plants surveyed): • Cost to adapt plant to changing standards and implement HACCP program (50,000 to 110,000) • Expected cost to maintain changing standards and HACCP plan- range (35,000 to 85,000)
Manarungsan Sompop, Jocelyn O. Naewbanij, and Tanapat Rerngjakrabhet (2005)	Shrimp, fresh asparagus, and frozen green beans	Thailand	Chemical drug residue reduction in shrimp; pesticide residue reduction in asparagus; chemical substance use restriction in frozen green beans	• In shrimp, the cost of using alternative chemicals was estimated to be $328/ton, or 1.6% of the total value of exports. • In asparagus, two firms were surveyed for compliance costs to farmers (US$/ha/year). After complying, the production costs of the two firms rose by 181% and 148% respectively. • In frozen green beans, after restrictions the costs for testing equipment went up by 33%. • Overall cost of quality control and testing went up by 1314%. • In all the above cases, costs to government for creating the systems such as labs or regulatory mechanisms was postulated.
Niang Papa Ndary (2005)	Fisheries	Senegal	Several health standards after the formation of European Union in 1993	• Overall, annual quality maintenance costs add up to approximately CFAF 5 billion, equivalent to 3 percent of average export earnings.
A. Nin Pratt et al. (2004)	Livestock products	Ethiopia	RVF free certi-fication by the government	• US $1 million cost to the government
Roy and Thorat (2008)	Grapes	India	Meeting GlobalGAP standards	• Average 35% of the value of production
Okello et al. (2007)	Green beans	Kenya	Compliance with food safety standards (public and private) in Europe	• Average cost to farmers: • In a farmer group – 4% of income • Large independent farmer – 24% of income • Small independent farmer – 68% of income
Asfaw et al. (2007)	Fruits and vegetables	Kenya	Meeting GlobalGAP standards	• Approximately 37,000 Ksh per group member to imple-ment EurepGAP and achieve the certificate • Main costs (30,340 Ksh) are for the buildings and facilities that farmers must establish in preparation to implement the standard. • These two cost elements comprise approximately 82 percent of the total cost and represent the one-time expenditures to set up the implementation. • The other 18 percent (6,660 Ksh) are the recurring costs of compliance (protective clothing, record keeping, salary for grader etc). The costs for external auditing, certifica-tion, training, and soil analysis were not included in the cost calculations.

Source: IFPRI GRP 40 document 2009.

GOVERNMENT/POLICY FAILURES

Poorly considered or rigid policies to improve food safety can exacerbate the problem instead of improving on market outcomes. Government policies, if poorly designed and/or implemented, can increase the vulnerability of poor consumers and farmers to exposure to unsafe food or zoonoses (Wu 2007). In Indonesia, where culling programs were initiated in response to HPAI outbreaks, inadequate monitoring and surveillance and poor incentive mechanisms encouraged farmers to under-report suspected cases and to quickly sell healthy-looking birds when a case of HPAI was suspected, increasing the risk of spreading the disease (Willyanto et al. 2010).

Without government intervention, markets alone can result in sub-optimal outcomes owing to various reasons, including imperfect information. Where premium markets exist for uncontaminated foods, and where food insecurity is prevalent, the poorest quality food with highest likelihood of contamination is likely to be separated out and consumed by the poorest. The negative impact on the health of these poor consumers is compounded by chronic malnutrition and immuno-deficiency, particularly in infants and children. Premium markets for safe food have undoubtedly played a vital role in providing the increased investments needed to improve food safety. However, the market alone cannot guarantee safe food for all consumers; the combination of pull from markets and push from public health and regulatory bodies is essential.

4.2 Specific problems faced by smallholders in complying with food safety requirements

Poor producers are more vulnerable when food safety standards require the implementation of costly procedures that are generally not recoverable through a commensurate price premium. Poor producers may lack the skills or financial resources to adopt prescribed procedures. Finally, economies of scale may work against small scale producers and other small-scale agents along the food value chain.

In addition to the relatively high costs of compliance, small scale producers face four distinct problems linked to market and governance failures:

1. How to produce safe food
2. How to be recognized as producing safe food
3. How to be competitive with larger producers
4. Asymmetry in information about food safety and market requirements and opportunities

HOW TO PRODUCE SAFE FOOD

The poor face the biggest constraints in terms of assets available to invest in technologies that mitigate food safety problems. Medium and large producers can access capital or credit to invest in the technologies or equipment required to meet international food safety standards, such as cold storage facilities for meat and dairy produce, clean storage facilities for staples, protective clothing, biosecurity measures, and so forth.

Poor producers face significant limitations in their ability to produce safe food due to limited access to resources. For example, aflatoxin contamination is most acute where crops are stressed pre-harvest due to drought or pest infestation. Poorer farmers on more marginal lands, who are less able to invest in fertilizers or other treatments, are thus most vulnerable to aflatoxin contamination in their harvest. This may especially impact women, who are frequently allocated the poorest land to cultivate their gardens in many parts of the world, though to an unknown extent. The problem of accessing clean water for irrigation is particularly acute for peri-urban smallholder farmers growing high value products to domestic urban markets. A study in Mexico examined smallholder cantaloupe production following the Salmonella outbreak in 2002, and found that water used for drip irrigation in the production of cantaloupe was the main source of contamination. The quality of water used for drip irrigation is a condition of the good agricultural practices (GAP) standards, and most small scale farmers were unable to meet this requirement. (Avendano et al. 2007.)

Due to information asymmetries, both the producer and the consumer may have limited knowledge of food safety problems, whether associated with inputs used in production or problems that occur in the processing and delivery of the product. Such problems can arise from the poor quality or the misuse of inputs or from the growth and transport of microbial pathogens and mycotoxins, which can be magnified as products move along the value chain.

In many cases, even if technologies are relatively inexpensive, requirements are constantly changing in light of new information, placing cost-effective risk reduction techniques out of the reach of most smallholder farmers, who have limited access to current information. The list of banned and approved pesticides and fertilizers is constantly changing and requires updating, as do the permissible level of chemical residues established by GlobalGAP; effective collective action can make such information readily available. The Mahagrape collective in India holds regular workshops where farmers and grape handlers and sorters (mainly women) are continuously trained and retrained in the latest grape growing and handling methods. There may also be opportunities for dissemination of simple technologies and information through mobile phones in the near future, as rural producers in some of the most isolated parts of the world increasingly become connected through mobile phone networks.

HOW TO BE RECOGNIZED AS PRODUCING SAFE FOOD

Small- and medium-scale producers may be excluded from growing markets for high-value agricultural commodities because they have difficulty guaranteeing that the products they produce meet mandated food safety and quality requirements. This difficulty can be due to a number of factors: stringent requirements (and costs) of recognized standards; lack of information among consumers, resulting in a lack of price premiums and incentives to produce safe food; lack of capacity to accurately diagnose and certify safe foods; lack of alignment of incentives along the value chain leading to contamination along the chain; and regulatory failures.

International food safety standards are increasingly driven through private standards such as the Global GAP, ChinaGAP, and KenyaGAP. In order to meet these GAPs, growers must keep records of fertilizers, irrigation, pesticides, and chemical applications and adopt specified management practices such as observing the proper time to harvest. These conditions can prove prohibitive for small-scale farmers, in the absence of substantial public or private investment in collective action and training.

Much of the research into improving food quality and food safety in developing countries has focused on the impact of international food standards. However, most food being produced in developing countries is also being consumed within developing countries. The problem of producing food that is recognized or certified as safe should be as important in domestic markets as international markets, if farmers are to recoup the additional costs associated with producing safe foods. If both buyers and sellers can easily ascertain the quality of the item being sold at the time of sale, as well as prices in alternative markets, there will be no asymmetries in information and the transactions costs of exchange will be low. However, if buyers cannot be sure of the true quality of the good they are purchasing, they will be less willing to pay a premium for it based on claimed quality.

Where the costs of compliance are not matched with a commensurate price premium in local markets, or where there is little or no monitoring or regulation among traders, retailers and other actors handling the foods, or where the incentives are not aligned along the value chain, there will be little incentive for farmers to invest in producing safer foods.

These regulatory failures are a significant aspect of developing countries and contribute to the under-development of value chains themselves. Government over-regulation, taxes, or tariffs can raise the cost of value-chain development and lower the benefits of participation for all members. Limits or bans on foreign investment may make it impossible for foreign participants to enter a market and bring needed technical expertise and coordination activities to a potential value chain. While the private sector has often compensated for government under-regulation by establishing private standards or certification programs, smallholders are left out of these privately structured HVA channels (Reardon et al. 2003). Even when regulatory norms are appropriate, changes in consumer demand can have negative impacts on smallholders, if retailer sourcing decisions change in response (Humphrey 2005).

Food contamination scares can have a crippling effect on producers who have no way of convincing potential markets of the safety of their produce. In Kenya, in May 2010, the government reported the results of aflatoxin testing from Eastern Kenya, stating that 70 percent of the maize harvest from 29 districts was contaminated and unsafe for human and animal consumption. These results were extrapolated to the region's production as a whole, leading to estimates that 2.3 million sacks of grain were contaminated, and blocking all marketing and movement of maize out of the area. Six months later, farmers were still left holding their maize and had started to consume it (Bandyopadhyay, personal communication; Daily Nation, http://www.nation.co.ke/News/Alarm%20over%202m%20bags%20of%20bad%20maize%20in%20market%20/-/1056/1061306/-/b5dj71z/-/index.html).

Loss of public confidence in the safety of a product from a particular region or country can also have a disproportionately large impact on developing countries at a national level. The case of the shrimp market in Benin is an example: loss of public confidence had a crippling effect on local producers and other actors along the entire value chain that had invested over decades in now-outdated infrastructure to support international marketing of shrimp. The Benin government implemented a self-imposed ban on exports of shrimp from 2002 to 2005, in response to sanitary problems identified by EU inspectors. 300,000 people along the value chain suffered during this period, as fishers, packers, and processors lost their jobs. The government, with international assistance, invested in transforming the industry, establishing new inspection centers and labs and building capacity by training fishermen and handlers on good hygiene practices to improve testing and handling capabilities. However, lost markets are difficult to recover, and in 2009 the market had yet to recover four years later, since European and other countries had found alternative sources. (WTO 2009.)

HOW TO BE COMPETITIVE WITH LARGER PRODUCERS

The stringent hygiene and food safety requirements common to many of the larger international supermarket chains come at a high price. Such large retailers often prefer to work with large-scale producers or with their own production operations that are inherently easier to monitor and regulate. Indeed, there is evidence that many companies, where they have the option, increasingly source primarily from large-scale companies (Reardon et al. 2009).

Larger producers and handlers have the obvious advantages of economies of scale, particularly where food safety standards entail fixed costs that are more easily affordable by larger companies. For example, handling and hygiene standards during harvest, grading, and packing of green beans in Kenya for a U.K. supermarket chain involved high fixed costs: growers were required to have a toilet, pesticide storage unit, and facility for hand washing. A case study among cantaloupe growers in Colima, Mexico, found that only 17 percent of growers sold directly to supermarkets, since they require packing facilities. The practice of late payments by supermarkets effectively cuts out altogether the participation of smallholder producers (Birol et al. 2010).

Points in the value chains that are characterized by scale economies thus create a basis for the exclusion of smallholders. Smallholders lack the scale to perform many of the actions necessary to be incorporated in HVA value chains, such as quality control, handling, and storage (Bienabe and Sautier 2005). Organizational constraints can further limit the participation of smallholders in HVA value chains. Where smallholders can participate in HVA value chains, they often lack the ability to realize possible upgrading or innovative marketing activities and are constrained by limited bargaining power that reduces the benefits for their participation and the ability to market products directly (Kaplinsky and Morris 2001; Farina et al. 2005). Delgado et al. (2005) suggest that transaction cost barriers also hinder smallholder participation in markets.

In their review of procurement practices of large retail and food processing companies, Reardon et al. (2009) cite a study in Chile that showed that fruit packing and export firms source only 10 to 15 percent from small farmers. In Kenya, large exporters had reduced the proportion of fruit and vegetables sourced from small-scale farmers from 45 percent of exports in the mid 1980s to just 18 percent by the late 1990s (Jaffee 1990; Dolan et al. 1999). In Argentina and Brazil, modern dairies have shifted from small to medium or large farmers to source products, as the processing sector has consolidated and multinationalized over the 1990s and intense cost competition emerged among processors.

Certification is also extremely costly and cannot be borne by individual small-scale farmers. Through its intensive training and capacity-building program, and the provision of required materials and technical standards, Mahagrapes in India has managed to provide grape-growing and -handling cooperatives with GlobalGAP certification at a much reduced shared cost (see Chapter 6). Members of cooperatives are also able to source inputs at a much reduced price through bulk ordering (Narrod et al. 2008).

ASYMMETRY OF INFORMATION ABOUT CONSUMER DEMANDS AND SAFETY STANDARDS

Information asymmetries between actors in the value chain serve to prevent producers from accessing high-value agriculture markets. Information regarding the health standards required by such markets is often not accessible to the smallholders, a situation exacerbated by a lack of coordination in the value chains. The exclusion of smallholders from high value markets, owing to production of low quality produce, could reflect lack of awareness regarding the market requirements. The geographic remoteness of many smallholders magnifies this problem of asymmetric information.

Informational constraints can influence the ability of poor producers to produce safe food or access lucrative high value markets in a number of ways:

(a) Incomplete information means that the strategies and payoffs of the agents are not known, and without complete information the outcomes of agents' actions may not be efficient.

(b) Imperfect information means that the actions of all players are not known, given the structure of the industry and the large number of actors along the value chain.

(c) Asymmetric information means that one party (for example, private producers) has more information than the other party (regulators).

(d) Any agent's actions against reducing the food safety hazard can cause spillover effects to the other agents ("externalities").

Under these conditions, market failure is known to arise. Government regulators may choose to intervene to correct the market failure and achieve more efficient reductions in the risk of a food safety hazard. Due to random events and the often complex interactions among players in the different value chains, however, it is not always clear to regulatory decisionmakers how to intervene optimally, particularly to ensure that poor producers participate in efforts to reduce the risk of disease.

4.3 Problems facing consumers

Consumption of unsafe food and water continue to be one of the major causes of preventable malnutrition, disease, and death. As with occupational hazards for producers, for consumers as well, a day lost to sickness is a day's lost income. An estimated 1.9 million deaths and 64.2 million disability adjusted life years (DALYs) are lost worldwide each year due to unsafe water, lack of hygiene, and insufficient sanitation (WHO 2009).

PROBLEMS OF AFFORDABILITY

Increased food safety standards can, perversely, negatively impact on the health of the poor in a number of ways. In many cases poor consumers cannot afford the higher prices associated with higher production costs to provide higher levels of food safety. Thus, higher standards may lead to reduced consumption of certain foods, which may lower energy or micronutrient intake. Proposed standards requiring pasteurization of milk in Kenya are one example (Kang'ethe 2005). There is thus a risk-risk trade-off between food safety and low-cost food supply for the poor, and this trade-off needs to be fully understood when policy decisions regarding food safety standards are being implemented.

Lack of information and understanding of food safety issues among consumers results not only in their failure to adopt measures to minimize health risks, but also in the absence of a price premium for safer food that would be an important driver for farmers to adopt best practices. In the absence of food safety regulations and adequate implementation of food safety standards in developing countries, there is potential for a situation in which high-value, high-safety products are destined solely for international or controlled, high-value domestic markets, while products produced more cheaply (for example, using high levels of synthetic pesticides or unsanitary waste water irrigation) are reserved for low-value local markets (Probst et al. 2010).

Nestlé Central and West Africa (CWAR) has established a program (as part of its corporate social responsibility project) to reduce mycotoxin contamination in grains, thereby improving market access among smallholder farmers. In Nigeria, locally sourced maize is supplied entirely to the domestic market, which recently adopted the same maximum residue levels (MRL) for aflatoxin as the EU (4 ppb). Under their Sustainable Agriculture Initiative Nestle (SAIN) program, Nestle trains farmers on simple but efficient contaminant prevention practices, and trains cereal suppliers and their agents on good post-harvest processing and storage practices (Johr 2010). Nestle CWAR has developed materials that describe best practices and dos and don'ts to reduce contamination, including cleaning out the chaff before storage and pulling out maize that shows signs of fungal growth before storing. As a result, the proportion of farmers that are able to sell their grain to Nestle has increased by orders of magnitude. Reducing aflatoxin levels overall should also benefit producers that consume their own crops, particularly when combined with information about the health risks of consuming maize contaminated by aflatoxin.

By educating farmers, consumers, food companies, retailers, and wholesalers on the health implications of mycotoxin-contaminated grains and legumes, Nestle promotes better health while creating a wider market for guaranteed aflatoxin-free products. As long as there is limited capacity to control for aflatoxin in local markets, such an approach makes good business sense, as it increases demand for branded products that carry an expectation of high food safety standards. However, there is again real concern that sorting, particularly in areas that are food insecure with few alternatives, could concentrate the poorest quality maize into the diets of the poorest household who may not have alternative food sources.

LACK OF ACCESS TO INFRASTRUCTURE

Many health risks that exist along the value chain in developing countries are due to poor infrastructure and lack of refrigeration facilities, as well as intermittent power to maintain refrigeration. In Kenya in the 1990s, the EU banned imports of Nile perch due to high loads of salmonella and contamination with pesticides. The ban was also influenced by the lack of hygiene and sanitation at the landing beaches and in the boats (Henson et al. 2000). While European markets may have been protected by the ban, local consumption continued unabated.

LACK OF ACCESS TO INFORMATION AND UNDERSTANDING OF THE POTENTIAL RISKS

Many health risks related to food safety along the value chain are chronic rather than acute, and as such are far less visible and easy to de-prioritize. Although aflatoxin is thought to affect around 30 percent of maize harvests every year in eastern Kenya, it only becomes a “national issue” on the years in which there are known fatal cases of acute aflatoxicosis. But chronic exposure to unsafe food and water can lead to stunting in children and immunodeficiency, resulting in greater susceptibility to disease, reduced labor productivity, and lower returns to human capital accumulation (schooling and training), and therefore reduced livelihood outcomes in both the short and long run. Alarcon et al. (2005) estimated that in the United States, as many as 7.4 schoolchildren per million suffered from acute pesticide poisoning. Disproportionate levels of exposure to health risks and effects are likely to be felt by women in developing countries who are pregnant or lactating and who also have comparatively low access to health services and protection of health standards.

LACK OF ACCESS TO HEALTH FACILITIES

Poverty is often associated with lack of access to health services, so poor people are less likely to receive adequate or timely treatment for poor health due caused by consumption of unsafe food and water.

4.4 PROBLEMS FACING OTHER VALUE-CHAIN ACTORS

Most studies looking at food safety along the food chain and impacts on the poor have focused on small-scale producers and consumers. The small-scale traders who transport goods between village markets and urban areas, and retailers who sell produce in markets and small stores have been largely neglected. Little is known about these actors, in terms of their socioeconomic and livelihood status generally or the specific impact of food safety issues.

Vertical integration and changes in procurement systems driven by large-scale markets and export markets, aiming to minimize health risks, will impact smaller actors throughout the value chain who do not have the advantages of economies of scale, including traders, small-scale wholesalers, and small-scale retailers. In India, traditional and small-scale retailers, wholesalers, and market workers have begun organized resistance movements in the face of the threat of large-scale corporate retailers encouraged by trade liberalization policies (Franz, 2010). These movements have been effective in driving public opinion and influencing political processes in some regions, even curtailing the operations of transnational corporations.

Few studies have analyzed the impacts of food safety on local traders in developing countries. Movement controls put into place during food safety outbreaks, such as the HPAI virus, significantly affected local traders, who overnight lost their livelihoods and income sources. In Kenya, the transformation of the market of Nile perch around Lake Victoria during the 1980s from a local market to an export market for processed fillets saw a rapid shift in the role of local traders. The traders became linked to the processing operations, selecting fish of particular size and quality, and in the process gained significant power in determining prices in what had been a highly decentralized local market. In the 1990s, however, the market collapsed due to EU concerns over hygiene facilities, particularly in the boats and landing areas, exacerbated by evidence of salmonella and pesticide contamination.

In Argentina and Brazil, private quality and safety standards in milk production and processing, combined with market liberalization in the 1990s, resulted in a stratification of the market, with large firms and multinationals controlling the milk industry and smaller farms moving into informal sectors such as cheeses, or leaving the industry altogether due to the increased production and processing costs (Farina et al. 2005).

The sellers of food may also face a “hidden action” problem vis-à-vis the producers. While the producers have to comply with the guidelines provided by the sellers of food to ensure standards, their actions in the production process are generally unobserved. This moral hazard problem implies a need for close monitoring, to ensure that the promised standard is actually provided.

5. Using a Modified Risk Analysis Approach to Reduce Food-Borne Hazards and Improve Health and Market Access for the Poor

What research insight can we provide to policy makers on how to reduce the health risk and improve market access for the poor—as producers, processors, and consumers of food? Implementing food safety standards requires processes to control food hazards along the whole value chain, but such practices may be costly. Value-chain actors’ price margins may be too small to allow them to alter behavior.

Historically, markets in less developed countries were characterized by interpersonal transactions in which the producer knew the consumer. Urbanization has resulted in the value/supply chain becoming longer, wider, and more anonymous; and institutions have not been developed to replace what a handshake could once achieve. The value chains in many LDCs are now much more complex than they once were, and though informal markets still exist where sellers and buyers know each other, with increased urbanization there are now more formal domestic markets emerging in many developing countries where transactions may be anonymous, with limited communication and coordination between farmers, traders, and consumers. In this environment, market participants have little incentive to reduce health hazards, owing to lack of coordination, small profit margins, and absence of traceability, as well as poor infrastructure, insufficient cold storage systems, and inadequate oversight and regulation. Several developing countries have obsolete public food safety laws, existing alongside the more stringent private requirements imposed exclusively on high-value export markets.

Faced with uncertainty about food safety outbreaks and control measures, decisionmakers are increasingly using analysis based on probability theory, and specifically risk analysis, to assist in making informed decisions regarding regulatory actions to prevent (or reduce) the incidence of disease associated with food safety and SPS concerns. There are three bodies involved in reviewing risk analysis involving food safety, animal, and plant health—CODEX, OIE, and IPPC— sanctioned by the WTO to set the standards for analysis.

The approaches vary to some degree, but the risk analysis typically consists of hazard identification, risk assessment, risk management, and risk communication. (For the purpose of the Codex Alimentarius Commission, risk assessment involves four steps: (1) hazard identification, (2) hazard characterization, (3) exposure assessment, and (4) risk characterization.)

Risk management for all groups involves an evaluation of how best to mitigate the risk, and an assessment of the cost to society of the mitigating action. *Risk communication* involves identifying ways to interact with the public, both as stakeholders providing needed input and as consumers of risk findings, to promote needed change.

5.1 The components of modified risk analysis

In developed countries, value chains, though complex, are monitored by a number of public and private institutional mechanisms to ensure safer food. Most of the producers have the means to implement risk-reduction measures in any given value chain. The risk analysis techniques used in developed countries may thus be inappropriate to developing countries, with the heterogeneity of producers and actors along value chains, and the importance of socioeconomic factors in shaping the choices of food-insecure actors.

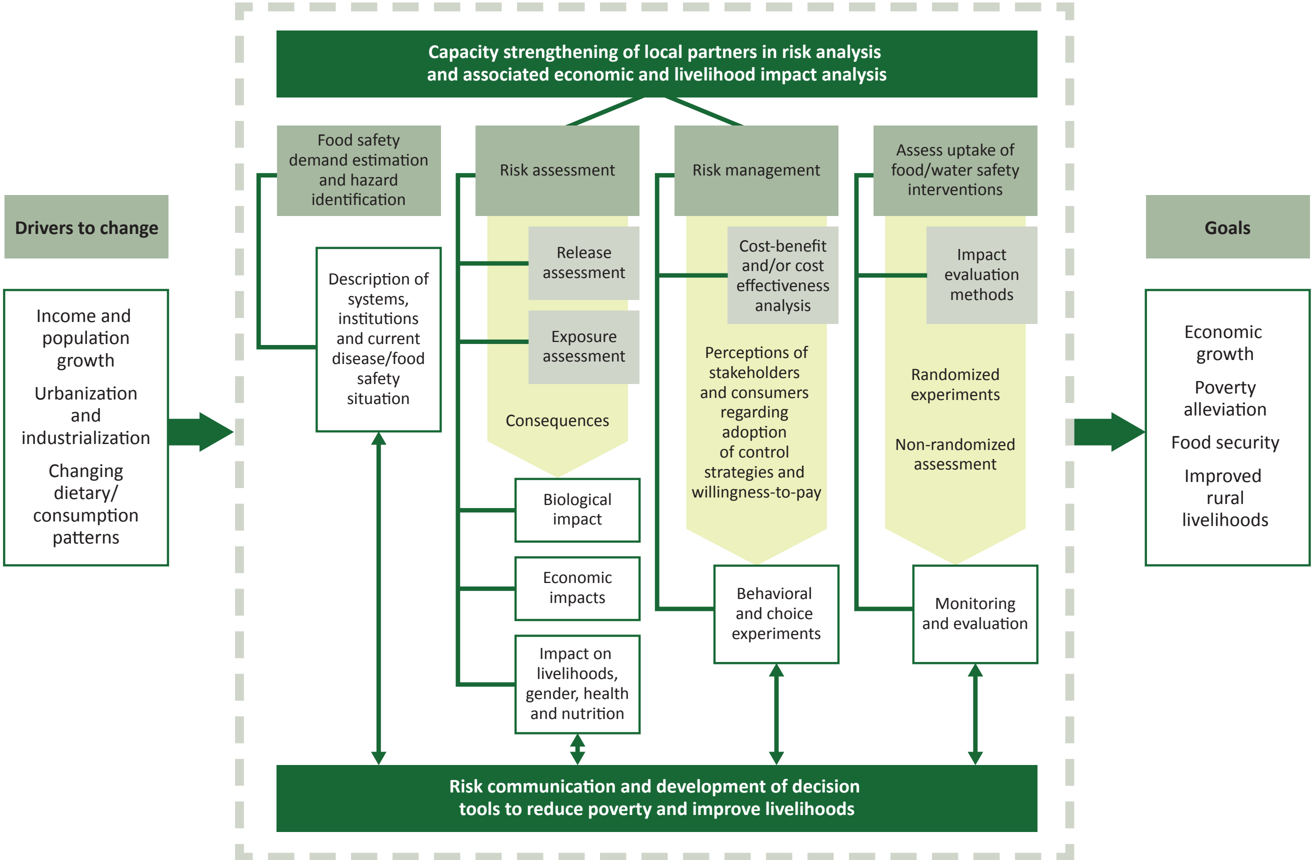
In a developing country context, finding sustainable solutions to improve food and water safety for the poor requires a broader approach. The numerous actors within a specific value chain create uncertainties regarding quality, especially as not all value chain and institutional actors are aligned to implementing risk reduction measures. IFPRI's Food and Water Safety team has begun to use a *modified risk analysis framework* (as shown in Figure 3) that augments the traditional risk analysis approach with a further analysis of the *behavioral factors* that may affect the adoption of risk reduction strategies. This approach is designed to provide additional insight into the decision making process, in order to further socioeconomic outcomes such as poverty alleviation, increased food security, and improved livelihoods (Narrod et al. 2009).

This modified risk analysis framework starts by examining the existing demand for reducing a particular food safety risk in a developing country context, and identifying the hazard. The risk assessment has four components: release assessment, exposure assessment, consequence analysis, and risk estimation. In the *release assessment,* all potential pathways for disease introduction are identified. In the *exposure assessment,* all potential pathways for exposure to food-borne diseases are identified. The *consequence analysis* assesses the impact on livelihoods at the household level. *Risk estimation* includes assessment of the uptake of control measures, the impacts of risk mitigation recommendations, and potential effectiveness of communicating the risk. The evaluation of risk management options, in addition to the traditional cost-benefit and cost-effective analyses, includes evaluation of factors affecting stakeholders' perceptions and behavior.

5.2 Food safety demand and hazard identification

Risk analysis does not usually include the estimated *demand* for risk reduction of the particular hazard. However, we know that in countries where a significant number of people are food insecure, consumers may be unable (or unwilling) to pay a premium in order to decrease the risk of exposure to a specific hazard. In such circumstances, when a producer or specific value-chain actor cannot charge a price premium for implementing a specific risk-reducing measure, the government may need to intervene. Cost-sharing approaches have been

Figure 3—Modified risk analysis framework



Source: Narrod et al. 2009.

used in the developed world to induce individuals to adopt specific measures that benefit society at large. But how should the government of a developing country intervene optimally, given the many socioeconomic issues that affect behavior?

In general, studies examining consumer willingness to pay for safe food reveal that consumers in developed countries are willing to pay higher prices for safer and higher quality food, and the demand increases with such factors as income, education, and food safety awareness levels. However, very few studies have investigated consumer demand for safer food in developing countries, and they generally rely on hypothetical constructed research contexts (Krishna and Qaim 2008; Ehmke et al. 2008; Roy et al. 2010). These studies find that in hypothetical settings, similarly to their developed country counterparts, developing country consumers also demand safer food.

Birol, Roy, and Torero (2010) tested for the demand for food safety in developing countries through a real market experiment (Box 2). They explore whether low demand for food safety in developing countries is only a function of low *ability to pay*, or whether lack of credible information and certification diminishes the willingness to pay for food safety. They found that suppliers continue to provide unsafe food primarily because of their assumption that food safety does not carry a premium in the market. Therefore, low standards of food safety prevail even in fast-growing developing countries like China and India. This also means that an important source of value addition is lost to producers. **Policies that provide credible information and certification could thus be an important factor in delivery of safer food and result in both improved public health and farm incomes.**

Improved domestic food safety standards could also reduce risk in uncertain export markets. Markets for goods with costly attributes, such as food safety, are assumed to be concentrated in high-income developed (importing) countries. Where domestic markets do not reward for providing such attributes, in form of a price premium, they fail to serve either as a source of diversification (and risk mitigation) or as a cushion against export market shocks.

Another means of assessing the potential for a premium price for safe food is through experimental auctions. One such technique is the Becker, DeGroot, and Marshak's (BDM) auction (Shogren 2005; Horowitz 2006). The BDM procedure is designed to be incentive-compatible (no conditions are attached), and it controls

Box 2—Consumers' willingness to pay for certified food products in India

Birol, Roy, and Torero (2010) implemented a market experiment in supermarkets in Mumbai, India. They provided a sample of customers with grapes procured from GlobalGAP (Global Good Agricultural Practices, formerly EurepGAP), certified grape producers who produce for the export market, along with information on certification in the form of brief documentation. The study tests the effect of credible certification (GlobalGAP) and information (the documentation) on consumers' willingness to pay for food safety. Those who received documentation were significantly more likely to purchase certified grapes than other customers, after controlling for different consumer and household characteristics. Credible certification resulted in an increased consumer demand for safer food.

The authors suggest investing in mechanisms such as certification and labeling and in institutions such as certification agencies, either by governments or by food industry, to facilitate the provision of credible information. The government of India is currently contemplating setting up an IndiaGAP standard. This research provides some early indicators for its potential positive impact.

for strategic response behavior (Becker et al. 1964; De Groote et al. 2010). The procedure is similar to a bidding game: respondents are given an incentive to announce their actual valuation of the food product, with clear instructions about how the bidding game works. After the respondent gives a price offer for a specific product, a buying price is randomly determined and compared to the price offer. If the buying price is higher than the price offered by the respondent, the respondent loses the opportunity to buy the product; otherwise, the respondent is obligated to buy the product at a price equal to the random buying price.

Currently, IFPRI is partnering with CIMMYT and ICRISAT to investigate the existing demand for aflatoxin-free maize (in Kenya) and groundnuts (in Mali), by implementing experimental auctions using real money and real products. Consumers are presented three different products of maize and three different products of groundnuts for auction: 1) clean produce without visual traces of molds or discoloration; 2) contaminated produce, with 5 percent damaged grains or clear evidence of molds and insect damage; 3) certified clean produce that has been laboratory-tested and labeled to show no traceable amount of aflatoxin (<2 ppb). These sample auctions will indicate the strength of consumer preference for visually clean as compared to certified clean produce.

MEASURING THE PREVALENCE OF AFLATOXIN IN GROUNDNUTS AND MAIZE ALONG THE VALUE CHAIN

In order to identify the most cost-effective measures to reduce health risks to consumers, it is essential to understand the prevalence of a particular hazard along the length of the value chain. One obstacle is the difficulty and cost of measuring the prevalence of hazards that are not evenly distributed in time and space.

A recent study sampled maize in Kenya and groundnuts in Mali—from farmers' fields (pre-harvest) and farmers' granaries and stores (post-harvest), as well as from various points along the value chain. The research objective was to generate a consistent database of aflatoxin prevalence along the maize and groundnut value chains, and to identify critical points where intervention strategies are likely to have the greatest impact. (Mahuku et al. 2010; Waliyar et al. 2010.)

A stratified random sampling strategy was used in both cases. In Kenya, maize samples were taken along three transects in different regions of Kenya that spanned different agroecological zones, in regions where there have and have not been known outbreaks of Aflatoxicosis. In Mali, groundnut samples were selected randomly from three of the principal groundnut growing regions, spanning different rainfall levels in western Mali. Post-harvest samples were taken at monthly intervals from the same households and traders, to measure changes in contamination levels over time.

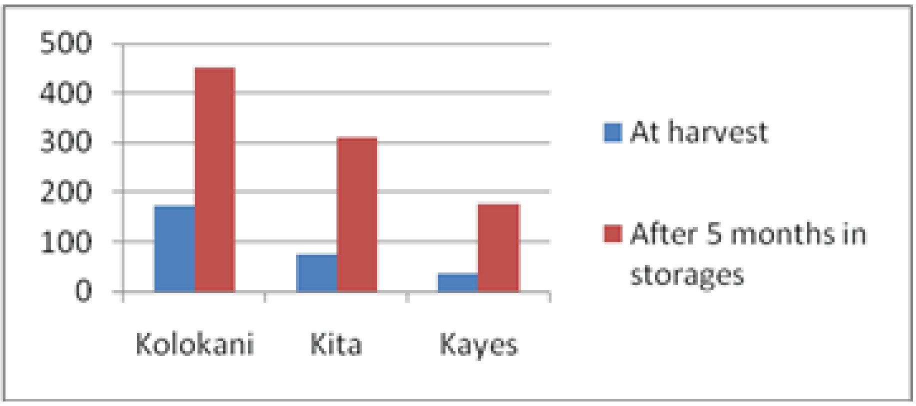
In Mali, the proportion of farmers found to have groundnuts contaminated with aflatoxin at levels greater than 10 ppb (the maximum residue limit recommended by CODEX) ranged from 35 percent to 61 percent across the three regions. Five months later, the range was 66 percent to 100 percent. Mean aflatoxin levels had likewise increased by up to five times the pre-harvest levels, at five months post-harvest (Figure 4).

Samples taken from traders in a local market showed similar increases. However, no such trend was visible in Bamako, where turnover is high and groundnuts are sourced from multiple markets and from imports. In Mali, many people cook with groundnuts in the form of paste that is frequently made from poor quality groundnut. Analysis of 720 samples of groundnut paste and seeds, taken over five months from small- and large-scale traders in Kolokani, found significantly higher levels of aflatoxin contamination in paste than in seed, with levels up to 1746 ppb. Variation within and between sites was generally high; future analysis will examine the degree to which this variation can be explained by environmental conditions or farmer practices (in both production and storage).

5.3 Risk assessment

In addition to the traditional risk assessment, the modified risk assessment also includes (as noted) a release assessment, exposure assessment, consequence assessment, and risk estimation. Prevalence data and expert elicitation can be used to implement qualitative and quantitative risk assessments along agricultural products' value chains.

Figure 4—Mean aflatoxin levels in farmer samples of groundnut in Western Mali (ppb)

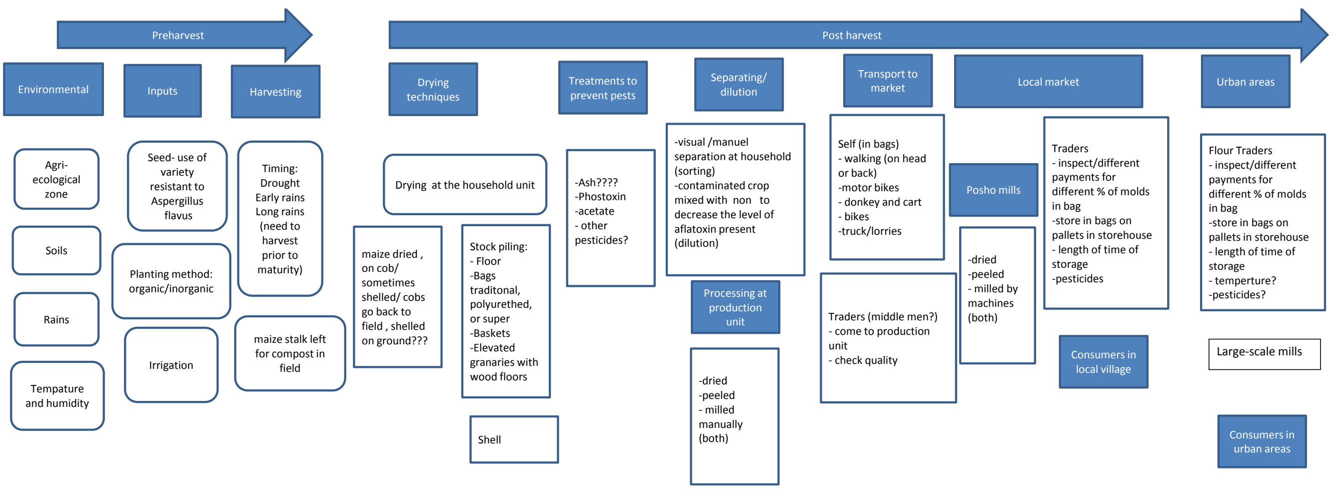


Source: Mahuku et al. 2010; Waliyar et al. 2010.

A baseline risk assessment focuses primarily on 1) screening risk scenarios to determine whether risks from a particular hazard have reached a threshold of concern along the value chains involving the poor; 2) estimating the economic impact of that disease both in terms of income and health; and 3) estimating the frequency of occurrence of the hazard at a particular location or at all locations along the value chain, to identify critical control points. In this section we describe how the approach is being used in the case of aflatoxin contamination along the maize and groundnut value chains in Mali and Kenya.

Though over the years several risk assessments have been performed for aflatoxin, most have focused on the toxicological endpoints, especially in relationship to exposure and potential disease impact. For instance, Bowers et al. (1993) estimated the carcinogenic risk posed by aflatoxin; Shephard (2008) quantified the risk of aflatoxin-induced liver cancer in Africa; and Chun et al. (2006) estimated the potential induction of liver cancer based on dietary exposure. Similarly, the Joint FAO/WHO Expert Committee on Food Additives (1998) performed a quantitative risk assessment on aflatoxin that estimated carcinogenic potency. Vardon et al. (2003) used a Monte Carlo analysis to estimate the cost of aflatoxin, deoxynivalenol, and fumonisin in the U.S. and

Figure 5—Potential places in which aflatoxin risk may be detected as maize moves along the value chain



Box 4. Assessing economic impact of health risks

As part of a study examining pro-poor HPAI risk reduction strategies, researchers at IFPRI and collaborating institutes estimated the potential effects of HPAI incidence on the income and welfare of households raising poultry. Six scenarios were simulated: 1) a country-wide shock where all poultry-producing households experience 100 percent loss of their poultry flock due to HPAI; 2) impact of HPAI on smaller-scale producers with poultry holdings of one to ten birds, if they experience 100 percent loss of their flock; 3) impact of HPAI on small-scale producers with between 10 and 500 birds, if they experience 75-85 percent loss of their flock; 4) 50 percent reduction in poultry price; 5) 100 percent loss of poultry flock in high-risk areas; 6) 75-85 percent loss of large-scale poultry flock in medium-risk area.

Results of the economic impact assessment revealed that households with between 10 and 500 birds were more vulnerable to HPAI shocks, in terms of livestock income and wealth, than those with fewer than 10 birds, across the study countries (Ghana, Ethiopia, Kenya, and Nigeria). Depending on the scenario, the country, and the disease risk level of the area (medium or high risk areas), the loss in total wealth was between 4 percent and 16 percent, and total annual household income loss was between 0.5 percent and 8 percent. Households with larger flocks were found to have diversified agricultural livelihoods strategies. Nevertheless, given the importance of poultry in their livelihoods, diversification of farming activities, savings, and investment in non-farm activities should be encouraged to help minimize adverse effects of HPAI shock on their livelihoods. (Birol et al. 2010)

estimated that the annual costs were likely to exceed US$1 billion. Liu and Wu (2010) used quantitative cancer risk assessment modelling to estimate the number of aflatoxin-induced liver cancer cases worldwide each year. No existing studies have tried to estimate how risk-prevention measures alter exposure, and how that in turn affects market access, income, and health.

In developing a risk assessment model, a pathway analysis is used to assess how the risk might alter as the product moves along the value chain. Figure 5 shows the initial pathway analysis for maize in Kenya. From this pathway analysis, it is possible to construct scenarios or event trees to derive a complete set of scenarios, showing all the potential propagation paths that can result in loss of confinement of the hazard following an initiating event.

The event tree is designed to reflect specific events (human actions or mitigative system operations or failures) in the value chains that lead to a hazardous outcome. This can be used to develop the probabilistic *risk assessment* to calculate the baseline aflatoxin risk, using seasonal prevalence data. The baseline probabilistic risk assessment model is designed to estimate the health and economic impacts of the hazard itself.

Box 4 describes an economic impact assessment of highly pathogenic avian influenza, focusing on income and welfare among poultry farmers operating at different scales and under different levels of risk.

5.4 Evaluation of risk management options at different points along the value chain

Cost-benefit analysis (CBA) is a tool commonly used by decisionmakers to systematically estimate all the benefits and all the costs associated with a contemplated course of action, in comparison with alternative courses of actions. The costs of an intervention and the benefits of its impact are often evaluated in terms of the public's willingness to pay to acquire its benefits or to avoid its risk. Costs can be estimated using any or a combination of the following approaches: economic-engineering analysis approach, cost survey analysis approach, econometric estimations of costs, and simulation (Fearne et al. 2004; Valeeva et al. 2004; Havelaar et al. 2006). In the economic-engineering analysis approach, the costs of an intervention are estimated for each individual procedure needed to implement it, and the total cost represents the summation of individual costs, including costs of implementing and monitoring. In addition to these structural costs are incidental costs (productivity losses) and market revenue losses that are related to detection of contamination or exposure. This approach also allows for efficiency analysis via estimation of cost functions based on available technical and economic data. The main advantage of the engineering approach is its transparency, as it is easy to understand how the numbers are estimated (Fearne et al. 2004).

Benefits can be derived from the reduction in economic costs, based on the costs associated with implementing each intervention, or from savings due to reduced costs of illness or beneficial changes in the composition of demand (Smith et al. 2007; Bennett et al. 2004; Disney et al. 2001). Benefits can also be measured in terms of losses avoided, such as loss of income and costs for treatment from the disease. For the measurement of health outcome, disability-adjusted life years (DALY) are used to facilitate the comparison of the economic risks and cost-effectiveness of various forms of interventions. Currently this approach is the best measure available for quantifying health benefits (or prevented losses), such as reduced cost of illness to consumers (including medicines, hospitalization, and doctor's consultation) and reduced productivity loss.

Once costs and benefits of risk reduction measures have been valued, a cost-effectiveness analysis (CEA) can be conducted to understand the risk-risk tradeoffs of the available risk reduction methods. For example, in the case of exposure to aflatoxin-contaminated food, information is needed on the economic costs of chronic exposure to aflatoxin (including infection, illness, and death); the investments and costs associated with different risk-reduction options; the probability of effectiveness of these various options; and the probabilities of chronic exposure under different risk-reduction measures.

Simulation can be performed using Monte Carlo process to different sets of scenarios: do nothing or no intervention (baseline); one intervention or a combination of interventions.

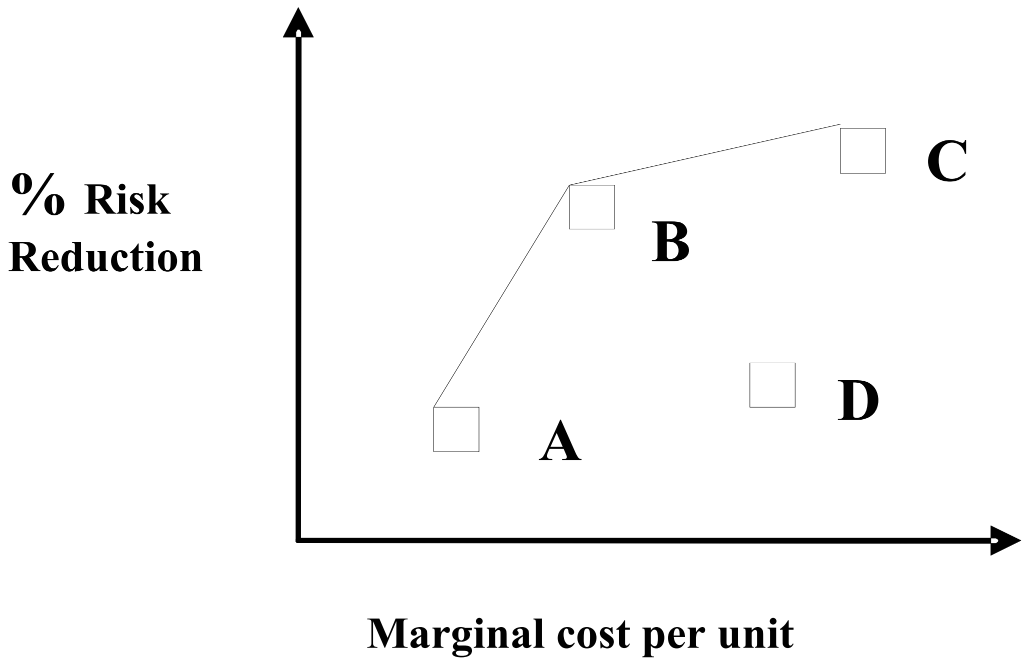
The difference between the baseline and a single intervention (or combination) is the gain in health (DALYs averted) or income due to the reduction in disease burden from the interventions. The costs of each intervention are then compared with the gains to identify the most cost-effective intervention (or a combination of interventions) at different levels of resource availability. The comparison of the different interventions against the most cost-effective pinpoints areas of efficiency; an intervention at higher resource levels shows what should be done if those resources become available. Such an approach would be useful for decisionmakers who may be interested in deciding after identifying cost-effective measures that the government could subsidize, if the poor are unwilling or unable to adopt such measures on their own.

To illustrate, consider four hypothetical options (A, B, C, D) to reduce risk. As shown in Figure 6, the x-axis is the marginal cost of adding one of the new options compared to the baseline. The y-axis is the percentage reduction in risk over the baseline. Option D can be excluded as a choice, since strategy B is superior to strategy D (both more effective and less costly). Choices of adoption strategy can thus be limited to non-dominated options A, B, and C: which one would result in maximum benefit for the available funding (Glauber and Narrod 2007; Malcolm et al. 2004). The choice between intervention C and B will depend on the political and economic feasibility of paying a premium to achieve marginally higher risk reduction.

The ouput of the CBA/CEA is an important input for risk management decisions. It helps policymakers weigh available options for reducing risk of illness, in terms of efficiency, technological feasibility, and practicality, at selected points along the value chain.

Though such approaches for evaluating risk management options are common in the developed world, such approaches are little used in the developing world, particularly for the value chains that involve the poor. Such an analysis provides insight into the rationale behind value-chain actors' understanding of the potential health risks associated with food contamination or use of hazardous inputs along the food value chain (Box 5).

Figure 6—Risk reduction-cost trade-off



Box 5—Analysis of knowledge attitude and perceptions to inform the feasibility of cost-effective interventions

In the HPAI risk-reduction strategies project, analyses of individuals' knowledge, attitude, perceptions, and practices were conducted sequentially. First, we estimated factors influencing knowledge about symptoms of HPAI using a categorical variable: a value of 0 if no knowledge of HPAI symptoms, 1 if low knowledge, 2 if some knowledge, 3 if medium knowledge. Second, the determinants of beliefs about good practices regarding handling of poultry and poultry products were estimated, to test the hypothesis that beliefs about good practices are in part influenced by knowledge about poultry diseases. Third, the determinants of perception were estimated, to test the hypothesis that perception is influenced by knowledge and beliefs. A perception index was defined as a categorical variable: the value of 1 indicates the producer is least concerned about disease spread within the village and the value of 4 indicates the producer is most concerned. Current practices on handling of sick birds, disposal of dead birds, and other practices were also estimated using indices ranging from 0 to 7.

Results showed that higher level of education and experience in poultry diseases is associated with higher HPAI knowledge, particularly for those producers with more than 10 years of education. Those producers with more knowledge of HPAI symptoms also have more correct beliefs about good practices in handling poultry and poultry products. Moreover, those producers with better knowledge of HPAI symptoms or more correct beliefs about good practices were found to have higher concerns about disease spread risks. Those producers that have had poultry disease in their flocks also tend to be more concerned about disease spread.

Knowledge and perceptions of health consequences of consuming food contaminated with aflatoxin is being assessed in the aflatoxin project, taking into consideration gender differences in perceptions, motivations, and behavior. It is hypothesized that, for households with higher knowledge about aflatoxin risks, the presence of risk induces changes in consumption and concerns about food insecurity, as well as causing lower income due to household's adopting new practices to avoid risk. Such behavior change thus comes at a cost, both indirectly in terms of opportunity costs and directly in terms of costs associated with risk-reducing strategies and risk-coping mechanisms (for example, recognizing and discarding contaminated grain intended for livestock). Knowledge about the health effects of aflatoxin may also prevent consumption of contaminated produce, resulting in better maintenance of the household's human capital (through the child nutrition pathway). Knowledge about aflatoxin contamination along the supply chain is also expected to influence decisions affecting market access for poor households, in order to improve their income and wealth.

Source: Authors' research.

Moreover, knowledge and perceptions about health risks can influence the individual's decisionmaking process and openness to risk-reducing strategies. Perceptions influence the formation of mental awareness, which is also affected by economic, social and cultural influences. The knowledge, attitudes, perceptions, and actions (what they actually do or choose to do) of value-chain actors are important factors in strategies to reduce food safety risks. Accordingly, assessing peoples' willingness to pay is important in estimating demand for safe food and in designing cost-effective ways to reduce health risks.

In a developing country context, where the source of health risks may lie with many thousands or millions of small holder producers, it is also vital to assess producers' and value-chain actors' willingness to pay to implement control strategies that are still in the experimental stage or not yet implemented or tested. Experimental auctions (described above) and contingent valuation techniques can assess not just the technical feasibility of a mitigation technique but its social and economic feasibility (Box 6).

5.5 Assessing uptake

The benefits of cost-effective options for the poor are of value only if they get adopted and the desired results actually occur. It is difficult to predict whether stakeholders really will respond to knowledge of what is most cost-effective. The final component of our modified risk analysis framework is not part of traditional risk analysis. Randomized trials are implemented to determine whether the identified cost-effective approaches will result in the desired uptake and will have the desired reduction in the hazard and its negative impacts on health and livelihoods. A community randomized trial in Guinea, West Africa (Turner et al. 2005) demonstrated that simple measures to improve storage of the groundnut crop on subsistence farms reduced exposure in individuals in the intervention villages by over 50 percent. In Kenya, maize is one of the main crops, eaten ubiquitously in the rural populations, and aflatoxin exposure levels are higher than in nearby Guinea: a recent study of blood

Box 6—Assessing willingness to pay for risk control strategies

In the HPAI risk-reduction project, a contingent valuation method was used to capture the willingness of smallholder producers to pay for control measures that would reduce the risk of HPAI infection and spread in the farm. A hypothetical market for six control measures independent of each other was presented to the participant. These services would be provided either by the public sector (veterinary services or para veterinary service in the district) or by the private sector (poultry input supplier).

The control strategies presented were:

1. Poultry enclosures of soft material (netting or cages) to prevent scavenging and contact with other birds
2. Use of footbaths for disinfecting feet when individuals enter the farm area, in addition to containment measures
3. Poultry enclosures of hard material (such as wood, bricks or mud) to prevent scavenging and contact with other birds, as well as with rodents and other contaminants
4. Regular disinfection of cages or coop made of hard materials
5. Vaccination of the flock against flu once every cycle (i.e., every four months) either by the public sector (veterinary services or para veterinary service in the district) or by the private sector (poultry input supplier)
6. Regular monthly monitoring by the veterinary services or by the poultry input supplier for disease, ensuring that any control measures are implemented appropriately and providing advice on how to adopt or improve the use of control measures.

Willingness to pay was estimated using questions that were open-ended with a single bid, and another one with follow-up bid, contingent upon the particular hypothetical market. In the open-ended format, the respondent was free to state the maximum amount they would be willing to pay (c.f. Brookshire, et al. 1983) when asked "How much are you willing to pay for measure x?" The second method used was an extended version of a single-bound, where the respondents were offered a particular price for the control measure (a starting value, randomly selected from a range of values bounded by the minimum and maximum cost of the measure if available in the market). In this situation the respondent faced a decision to purchase or not based on that starting value. A follow-up question was asked: "what is the maximum price you are willing to pay for the control measure?"

Source: Authors' research

samples from children (ages 6 to 16) in Makueni District in Kenya found traces of aflatoxin exposure in 399 out of the 400 sampled (C. Wild, personal communication).

This part of the analysis of aflatoxin in Kenya will involve a randomized trial of improved maize storage, using an educational package aimed at subsistence farmers and incorporating a cost-effectiveness analysis.

In sum, quantifying the impacts of food-borne and animal diseases on human health is important in order to provide decisionmakers with evidence-based assessments of the economic efficiency and technological feasibility of specific risk reduction strategies at selected points along the value chain. Quantitative analysis is more difficult, however, when there are several risk pathways to be considered along as well as potential reactions and behaviors of market actors and consumers. For instance, consumers may lose confidence in the safety of products as a result of a food-borne or animal disease outbreak, leading to market-share losses due to decline in demand for food products. Consumer responses usually depend on the information they have, their level of knowledge, and the changes in relative prices when making choices about food products to purchase or consume, particularly if there is a food safety issue that would affect their wellbeing. Consumers' decisions, like those of value-chain actors, need to be taken into account in evaluating costs, benefits, and effectiveness of alternative interventions.

6. Current and Emerging Opportunities for Cutting Health Risks Discussion along the Value Chain

Much of the policy focus on food safety in developing countries has concentrated on access by producers to export markets, where SPS standards can present significant barriers to exports (Balsevich et al. 2003). Unless the SPS standards can be met, countries cannot export products regardless of the food safety attributes.

However, with rising incomes and other lifestyle changes (such as urbanization and access to information), improving food safety for products in domestic markets is potentially of greater significance to poor producers as well as consumers. In 2003, it was estimated that Latin American domestic supermarkets bought roughly 2.5 times more produce from local producers than was exported from the continent (Reardon et al. 2003). These large-scale and increasingly multinational retailers, while raising concerns about local power relations and fair trade, undoubtedly present an important opportunity for improving the livelihoods of small-scale producers and, in many cases, of women who gain employment—as well as providing reliable sources of produce (Henson et al. 2005).

This change in the domestic markets poses new challenges for farmers but also offers great opportunities. The challenge arises from costs of compliance, in the absence of a price premium to compensate for ensuring safe food. The opportunities are less obvious. Besides enhanced domestic food safety, standards offer other potential benefits. They diversify the market for products with high food safety standards, as premium markets can be accessed locally. Geographical proximity reduces the potential for spoilage in transit; so domestic standards may be easier for farmers to meet than the additional requirements for exporting HVA to distant markets. Finally, the cost of enforcing and monitoring standards creates an incentive for government agencies to educate consumers and producers, fostering a greater willingness to pay a premium for food safety as incomes increase.

The focus on international markets also diverts attention from the fact that a very high proportion of produce (particularly staples) in developing countries is consumed without ever reaching a market.

Analysis of key points of entry needs to take into account different value-chain actors, and their incentives to ensure the delivery of safe food. Which markets are available to smallholders? What agrifood industries (food processors or large-scale or multinational retailers) or other actors are influencing the value chains, through provision of market opportunities and imposition of private standards? What is the local institutional context in terms of regulatory or diagnostic capacity? What are the opportunities for market versus public health approaches?

We have identified four main channels for action in reducing health risks along the value chain for the poor in developing countries:

1. Addressing problems arising from asymmetry of information in quality and safety of food and water
2. Addressing problems arising from market power through product differentiation
3. Addressing problems arising from the political power and government failure in establishment and implementation of food and water safety standards
4. Identifying cost-effective low technologies to reduce health risks along the value chain

In the context of food and water safety, these four issues are not independent but interrelated.

6.1 Addressing problems arising from asymmetry of information

It is widely assumed that higher prices and low ability to pay are the main factors preventing consumers from paying a price premium for safe foods—overlooking the importance of another factor, the lack of awareness of health risks among value-chain actors in developing countries. Many developing country consumers are at most partially aware of the health risks associated with unsafe food and water. Awareness and income are difficult to distinguish, given that both increase with education levels. However, there is evidence that lack of information on the part of consumers can be a significant factor in the price premium placed on safe foods by the poor in developing countries (Birol et al. 2010; Probst et al. 2010).

Asymmetry of information implies not a lack of information, but a situation in which there is an informed party and an uninformed party. This asymmetry works in both directions along the value chain. For example, with some degree of vertical coordination, the producers, handlers, and to some extent retailers of food know the inputs used in production, handling, and processing, while the consumers do not. Conversely, many small-scale farmers are physically and economically isolated and unaware of what consumers are looking for when they purchase foods. Creating a link between producers and consumers is a prerequisite to creating incentives for producing safer food.

Furthermore, for the majority of health risks along the value chain, the credible information needed by consumers must be sourced from third party. This requirement is a function of the fact that food safety is a credence attribute. Many of these health risks are chronic and cannot easily be identified or attributed to specific products: for example, trace residues of chemical pesticides do not immediately change the consumer's experience of eating an apple, although accumulated over time they may be highly carcinogenic. The risk that the product poses to the consumer can be known only to those with knowledge of the value chain, or with the capacity to test for hazardous pathogens or residues. The source of this information must be trustworthy to the consumer. Multinational companies tend to attract a higher level of trust, due in large part to the high spillover risk to their profits were it to become known that their food was contaminated. To create a credible system to certify smaller producers, working through third-party audits, presents a challenge in developing countries.

There is a need for credible institutions that can address the problem of attribution, to the best extent that science allows. Alternatively, institutions entrusted with delivering food safety need to be made accountable. Even in developed countries, institutions struggle with ensuring food safety for health impacts that are not directly experienced by the consumer but accumulate over time. With more limited scientific and institutional capital, developing countries are likely to find it much more difficult to develop and maintain realistic and effective standards.

In contrast, individual retailers, with little longevity in the market, can have little credibility with regard to certification of health standards. Furthermore, implementing food safety standards implies having processes in place to control food hazards along the whole value chain, as many food safety hazards stem from problems associated with inputs into production, and may be magnified as products move along the value chain. However, the value chain in many LDCs is currently based on anonymous transactions in spot markets, implying limited communication and coordination between farmers, traders, and consumers. This lack of coordination, coupled with poor infrastructure and insufficient cold storage systems, creates an environment in which market participants have little incentive or ability to reduce microbial pathogens and pesticide residues. Further, the problems of moral hazard in terms of hidden action are compounded by the length of the chain, jeopardizing the final outcome in terms of food safety.

RESOLVING THE INFORMATION PROBLEM

In a situation of asymmetric information, both informed and the uninformed parties can take some action to mitigate the problems of adverse selection. Informed parties can use signaling mechanisms, such as a system of credible certification, to address the information problems, particularly where markets exist that can support price premiums for safe food. The uninformed party (mainly the consumer) can also institute mechanisms to screen food products for safety. For example, consumer groups could employ independent scientific experts to test for residues.

The increasing prevalence of private food standards, established by local or multinational corporations or trade associations and retail groups, represents a signaling mechanism by the informed party. The proliferation of private standards reflects the lack of credible public institutions to signal quality (including food safety attribute). Reardon et al. (2009) suggest additional reasons for the expansion of private standards, as a means to engender product differentiation and create competitive advantage.

Whatever the motive behind development of private standards, the costs associated with developing, implementing, and monitoring them can be recouped only if consumers are aware of the standards, creating an incentive on the part of retailers and others implementing agencies to keep consumers informed. Such mechanisms do not rely on government to provide certification, although clearly governments have a role in providing oversight to any systems of standards. Studies have demonstrated the effectiveness of certification and provision of information in creating a demand for safe produce (Birol et al. 2010).

Nevertheless, for most developing countries, where produce is sold by individual farmers at local markets or sourced through small-scale traders and retailers, consumers remain dependent on government and civil society to address the information gap.

While there is evidence that information may incentivize consumers to pay more for safe food, access to such information is frequently incomplete or inconsistent. During informal interviews, farmers in eastern Kenya were highly aware of the problem of aflatoxin contamination and the fact that it had led to severe cases of sickness and death when people (mostly children) had consumed maize contaminated with high levels of the toxin. However, they were less knowledgeable about the long-term chronic impacts of aflatoxin exposure. Equally, they had incomplete information about how to evaluate the risk of aflatoxin contamination, associated with the growth of fungus: when asked if they would ever consume moldy grain, having initially insisted not, respondents finally said that they only ever eat moldy grain if it is from their own farm as they “know that it is safe.”

There is an essential role, therefore for governments, together with multinational institutions responsible for public health (such as WHO and CDC), to inform populations of the health risks found along the value chain and how to address them, whether as producer or consumer.

KNOWLEDGE AND DATA GAPS IN PREVALENCE OF FOOD SAFETY RISKS

Another fundamental gap in knowledge and information relates to the data on the prevalence of health risks worldwide, and particularly in developing countries. Accurately estimating and interpreting the prevalence of food safety risks along the value chain is of fundamental importance to minimize human health risks associated with food safety worldwide. In developing countries, however, formal data and information networks tend to be weak and scarce, and accurate information is difficult to obtain.

The multiple points of origin and health implications of food safety risks—and their high degree of interconnectedness along the value chain—make the task of accurately quantifying each risk difficult at best. A disturbing example of this complexity is seen in estimates of diarrheal diseases. WHO estimates that in 2008, more than 1.6 million people died of diarrheal diseases worldwide: approximately 11,000 in high-income countries; 129,000 in East Asia and Pacific; 29,000 in Europe and Central Asia; 47,000 in Latin America and the Caribbean; 68,000 in the Middle East and North Africa; 545,000 in South Asia; and 863,000 in Sub-Saharan Africa (WHO 2009). Collating these "endpoint" diarrheal fatalities with their respective pathogenic origins and sources of contamination along the value chain is a daunting task. As shown in Table 3, diarrhea is a symptom of a number of different food- and water-borne pathogens, in a wide variety of foodstuffs. Quantifying the relative contribution of different pathogens along the value chain to the endpoint diarrheal fatalities will require significant coordination and information-sharing among stakeholders. Even then, estimates will continue to be imperfect.

Over the past decades, the United Nations Food and Agriculture Association (FAO), the World Health Organization (WHO), the Center for Disease Control (CDC), and the International Food Policy Research Institute (IFPRI) have begun to address these critical information gaps. In 2006, WHO launched the Initiative to Estimate the Global Burden of Foodborne Diseases, establishing the Foodborne Diseases Burden Epidemiology Reference Group (FERG), with the objectives of (a) modeling estimates of food born disease burdens, (b) providing tools for country-level analyses, and (c) undertaking country-level surveys to estimate global risks. The Initiative anticipates producing a database on food safety risks worldwide by 2013. Efforts such as this—along with increased communication and knowledge-sharing along all points of the value chain—will be essential to better understand the prevalence of food safety risks. More broadly, efforts that combine the collective expertise of agricultural and trade economics, public health, microbial ecology, food policy, and the nutritional sciences will be critical to assessing and understanding these risks worldwide.

6.2 Addressing problems of market power inequities

The emergence of food and water safety standards can lead to inequitable access to markets or market power, in two ways:

- Fixed costs of compliance (such as provision of sanitary facilities) to meet food and water safety standards are often prohibitive for small farmers.
- Emergence of product differentiation, with safe food becoming available only to the wealthiest consumers, may in some cases exacerbate the problems of unsafe food among the poorest consumers.

However, the exclusion of small-scale producers can be mitigated through appropriate institutional solutions. Producer organizations (either alone or in collaboration with marketing partners) may circumvent diseconomies of scale, as in procurement and processing of information and other fixed costs. Public-private partnerships can sponsor and provide training for independent certification agencies or other facilities. These approaches all have the potential of reducing the transaction and fixed costs borne by individual producers, through vertically coordinating production, handling, marketing, and processing (Eaton and Shepherd 2001),

The rise in private quality standards implemented by large-scale agrifood businesses are playing an increasingly significant role in influencing value chains (Henson and Reardon 2005; Reardon et al. 2009; Jaffee and Masakure 2005). These standards can also influence the value chains for small-scale farmers, providing motivation for them to invest in approaches that improve the safety of the food they produce and consume.

CONTRACTS AND COLLECTIVE ACTION AND THE ROLE OF LARGE-SCALE AGRIFOOD INDUSTRIES

Overall, the shift towards highly competitive multinational companies dominating the marketplace has resulted in driving prices down, disadvantaging small-scale farmers, while imposing additional costs (to meet quality standards), which are frequently fixed and therefore harder to bear. However, some interesting exceptions provide useful clues in seeking key entry points for pro-poor safe food production (Reardon et al. 2009).

- In a sector dominated by small-scale farmers, such as tomatoes in Guatemala and guavas in Mexico, sourcing from large-scale producers is a challenge; leading chains have been found to source preferentially from small farmers.
- Larger farmers may be considered a more risky source, where they have a broader set of market options (such as exports versus domestic markets, in a variable price environment).
- In Guatamala, Von Braun et al. (1989) found evidence of large-scale exporters shifting from own production to small farmers for production of vegetables, because of the capacity of small family farms to supervise family labor and ensure more care in production and handling practices.
- In India, cooperatives and collective action have created effective competition to large-scale producers, by providing more care in their production practices due to the low cost of family labor while benefiting from economies of scale in terms of sourcing inputs and infrastructure requirements (Birthal et al. 2008).

These examples show that vertical coordination through collective action can help to lower the transaction costs and market risks faced by smallholders in competition with large-scale producers.

A fundamental feature of these arrangements, in addition to collective action, is the existence of **contracts between small-scale farmers and retailers**, to ensure quantity and quality in supply from an otherwise fragmented and unregulated base. Contracts provide a crucial institutional mechanism allowing producers to form constructive partnerships with agribusinesses and to benefit from the market potential of high value agriculture (Eaton and Shepherd 2001). Contracts provide an incentive to the supplier to stay with the buyer and, over time, make investments in assets (learning and equipment) in line with retailer's specifications. Retailers are assured of on-time delivery of products with desired quality attributes. Contracts may occur between retailers and producers or between food processors and producers. For many small-scale producers, contracts provide the only means to remain competitive (Eaton and Shepherd 2001). Moreover, contracts linked to private food safety standards and conformity with regional standards have resulted in enforcement of public standards that had previously been disregarded. However, where contracts involve working with small-scale producers and traders, they may be very costly in terms of the transaction costs of working with multiple farmers, particularly at the outset. Measures that facilitate compliance, incentives to reward good performance, and penalties to punish non-compliance can reduce those transaction costs (Henson et al. 2005).

Resource-providing contracts (Reardon et al. 2009), in which the purchaser of the produce provides a range of inputs, can enable small-scale farmers to provide high quality, safe foods, increasing household incomes and at the same time in many cases improving productivity (Box 7).

Collective action can be an effective means for farmer groups to bypass intermediaries and become involved in marketing produce themselves or with a marketing partner. However, collective action also comes at a high cost. The provision of education, infrastructure, value-chain organization and other resources requires financial backing, whether from industry, donors, or NGOs (Boselie et al. 2003). Eaton and Shephard (2001) list the multiple preconditions necessary for successful contract farming to assure access to a profitable market in the long term: conducive physical, social, and cultural environments; communication and infrastructure; availability of land and necessary inputs; and a supportive legal and policy environment. Henson et al. (2005) describe the continued adaptation required to ensure sustainability of a contractual arrangement with multiple farmers in a constantly changing market environment.

However, working with multiple farmers imposes significant costs on exporters, in terms of the continued support and monitoring required to ensure compliance with standards, and (where importers insist on it) traceability (Box 8). Contracts also impose costs on farmers, in terms of the risks associated with changing practices, lack of a market for remaining produce, unreliable or exploitative purchasers, corruption in the allocation of quotas, and the risk of long-term debt based on excessive advances (Eaton and Shepherd 2001).

Box 7. Mahagrapes in India (Roy et al. 2007)

In India, a marketing organization called Mahagrapes was established to facilitate export of grapes to high standard European markets. Mahagrapes at first faced high rates of rejection. The government provided active support, akin to infant industry protection, in a positive example of public-private partnership.

Mahagrapes enables farmers to ensure their compliance with IFSS through collective action: holding workshops to disseminate information on the standards to member farmers; informing and training farmers and grape handlers/ sorters (primarily women) in current grape-growing and handling methods and processes; updating the list of banned and approved pesticides and fertilizers, and permissible levels of chemical residues, which vary with time and across markets.

All this information is published in the form of a yearly handbook in the native language, distributed free of charge to members. Mahagrapes also provides materials and technical help along with infrastructural support to facilitate the implementation of the standards. Regular and constant monitoring of the grape plant by the scientists from the government National Research Centre (NRC) in Pune is provided to ensure that the plant remain healthy throughout the year and not just in the fruiting season. Bio-fertilizers and bio-pesticides are developed and produced by Mahagrapes and provided to member farmers at low cost.[9]

Box 8. Contract production of Fresh beans in Kenya

In Kenya, two forms of contract production have enabled market access for small farmers in fresh beans: contract production for an exporter, either with individual farmers or with farmer groups. The farmer groups have technical assistants or trained leaders that help members meet the standards. Buyers work very closely with groups in providing training and other technical support and facilitate their compliance with the standards. The farmer organizations conduct training for members and facilitate farmer-to-farmer monitoring, in the absence of the exporter's field technical assistant (TA) or to reinforce exporter's training. The organizations invite experts to train farmers on GAPs, especially the observance of pre-harvest interval following application of pesticides, integrated pest management, packer hygiene, and how to establish and maintain a functional traceability system. In establishing systems where smallholders can meet the standards, the bulk of the donor and NGO funding has focused on three areas: EUREPGAP compliance and certification, access to information and capital, and market access for the compliant farmers. This has taken the form of sponsoring their EUREPGAP training, audits, and certification. These projects are provided through partnerships within the private sector (donors and NGOs) and between the private and public sector.

Over time, however, the potential savings of growing such a labor-intensive crop (Collins 1995) has been outweighed by the transaction costs of working with multiple farmers, resulting in exporters shifting towards partnerships with medium- and large-scale farms to source green beans (Jaffee 2003). In Kenya, the share of the green bean industry held by smallholder farmers declined from more than 60 percent in the early 1990s to less than 40 percent by 2000.

Source: Okello et al. 2010

REACHING THE UNREACHABLE

Traders and transport agents, particularly small scale in either rural or urban environments, are often excluded from contract or other collective actions; unfortunately, they frequently represent the weakest link in terms of spreading, maintaining, or exacerbating health risks along the food value chain. Unless traders are included in some type of program scheme to invest in mitigating health risk, such as certification schemes or education, they have little incentive to address these problems. These groups represent a major challenge in promoting safer food and reducing risks along the value chain, being self-employed, highly mobile and highly diverse, with little traceability, particularly in urban areas. They may also be particularly hard-hit by outbreaks, as was apparently the case during the HPAI outbreak when movement of poultry was largely banned, until they transferred to other products. Although transporters were considered highly influential in prolonging and exacerbating the spread of the disease, very few ways have been developed to reach and influence them. The producers that

[9] These inputs are also sold to non-members but at higher prices implying cross-subsidization.

depend on them bear the greatest cost, particularly where poor storage or transport practices result in the contamination of previously safe food—and subsequent loss of confidence in the source.

6.3 Addressing problems of political power and government failure

Supermarkets are now a major driving force in agribusiness worldwide. Locked in competition with each other, these national and multinational corporations are constantly looking to improve their margins, increasing their market share through providing better quality produce at a cheaper price. In domestic markets, this creates a potential conflict between driving down costs while demanding higher quality and often (but not always) safer food, which comes at a price. Improving government capacity to monitor and regulate food safety standards is essential. The growing reliance on private food standards over the last decade is due in large part to governments' failures to enforce their own legal standards, leading to a lack of credibility among suppliers and consumers.

Regulatory failures even in developed countries have been common with regard to food and water safety. The scope for regulatory failure is even greater in the case of developing countries, with limited resources and capacity and a highly diversified and fragmented agrifood sector based in large part on small-scale production. As with market failures, there can be several reasons for regulatory failure, such as asymmetry of information, elite capture in governance, or even pure corruption.

Furthermore, market solutions to food safety are irrelevant in situations in which producers largely consume their own food. Subsistence farmers are unable to benefit from any price premium, so their incentives to change production or consumption behavior to improve food safety must be entirely based on health costs. This is particularly challenging for public health policymakers and agents of change, where health risks due to food safety are chronic and households are faced with insufficient food reserves to feed their families. Moreover, most health risks along the value chain tend to be intangible, resulting in less incentive to act.

All the proposed solutions rest on institutional support in the form of government's capacity to create credible systems and to punish those responsible for food safety failures. Across developing countries, however, government institutional capacity to monitor and enforce food safety is limited. In Mali, there are no national policies or institutions setting up standards and norms related to aflatoxin levels in the local or regional markets; and even if such norms and standards were developed, their enforcement would be weak due to lack of institutional capacity and understanding of the relevance of the issue (Ndjeunga et al. 2009). This is a major area for future investment in reducing health risks along the value chain.

BOX 9. Nestle's milk purchasing program in India

Nestle's milk purchasing program provides an example of how a confluence of multiple factors, including direct government interventions, is sometimes required to create a situation in which it makes financial sense for a large company to source its product from multiple small-scale farmers.

In the 1950s, the Government of India introduced a series of protectionist measures to regulate imports, which effectively gave the company a choice of purchasing milk from local farmers or leaving the market (Joshi et al. 2007). Land tenure and resource pressure in the region were such that the market was effectively dominated by small scale dairy. By 2001, Nestle India Limited had contracts with over 85,000 farmers in 1002 villages to supply its milk processing factory in the town of Moga in the northwestern state of Punjab. (Dhaliwal 2003; Birthal et al. 2005). The company supports collectors as well as producers, providing refrigeration at collection points along the value chain.

6.4 Identifying cost-effective risk-based technologies to reduce health risks along the value chain

Finally, while institutional arrangements can make or break any attempts to address food safety along the value chain, ultimately low-cost preventive technologies and improved production and processing practices are required that are accessible to small-scale farmers (who are often subsistence farmers and consume their own produce). Likewise, low-cost technologies to diagnose the hazard will play a vital role in reducing health risks along the value chain. Strategies to minimize the risk of a health hazard in the value chain require a detailed knowledge of the pathogen or toxin, how it enters the food chain, its prevalence and spread, and mechanisms to reduce the likelihood of its occurrence. Ultimately, however, any investment in technologies or practices to reduce health risks will depend on the perceptions of producers or consumers regarding its benefit, in either financial or health terms (Box 10).

Box 10 Reducing aflatoxin contamination in staples: technological and institutional constraints

Aflatoxin is a toxic by-product of two species of fungus (Aspergillus flavus and Aspergillus parisiticum) that is commonly found in soils across the globe. There are multiple strains of Aspergillus spp, of varying toxicity. Hot, dry conditions during flowering, particularly drought conditions, increase the likelihood of spores from the soil contaminating a crop pre-harvest. Moist, humid conditions, particularly where grains are exposed to soils that contain the fungus, exacerbate the likelihood of contamination post harvest. Storage in warm, humid, aerobic conditions further increase the risk of fungal growth and accumulation of aflatoxin at levels well beyond internationally recognized maximum residue limits. (CODEX limits safe levels of contamination of Aflatoxin B1 to 10 ppb for human consumption.)

Aflatoxin contamination can take place pre- and post-harvest, and levels of contamination can continue to increase throughout the value chain, whether the crop is held in a farmer's store for home consumption or transported and stored by traders, retailers, and wholesalers (Waliyar et al. 2010). In Mali, where aflatoxin contamination of groundnuts is prevalent, analysis of nearly 5,000 samples taken from farmers' fields and granaries and from traders and retailers in rural and urban markets found almost 50 percent of samples contained more than 36 ppb. Aflatoxin levels in farmers' stores increased by between 261 and 521 percent across three study areas over five months post-harvest.

At present there is very little awareness of the health issues associated with aflatoxin among producers and consumers in Mali, and a lack of human and technological capacity and political will to address the problem (Ndjeunga et al. 2009). A number of low-cost technologies to reduce exposure to aflatoxin pre- and post-harvest have been tested (drying produce on tarps, applying lime and fertilizers at critical points in the growing season, drying groundnuts with the pods raised to the sun, drying and treating groundnuts with pesticides prior to storage). However, with little awareness of the impacts or extent of contamination among producers and consumers, and no price premium for aflatoxin-free groundnuts or groundnut products, there is little or no incentive for producers to invest time and effort into these technologies.

7. Conclusion

Safe food is a public health priority and a fundamental element of food security. Changing diets, an increased demand for high value agriculture—in particular perishable produce, such as meat, dairy, vegetables, and processed foods—and the globalization of these markets present a major challenge for food safety as well as an opportunity to poor producers in less developed countries.

While food and water safety is still a nascent policy issue for many developing countries, it is increasingly commanding the attention of decisionmakers because of increased adverse impacts on the health and livelihoods of people and livestock, as well as potential trade impacts. Food and water safety risks, along with demands for addressing them, are likely to magnify in the future. Increasing incomes will continue to drive diversification of consumption and boost demand for increasing quality, as well as quantity, of production, as has occurred in the developed countries. In addition, global warming is expected to exacerbate many forms of water pollution—including sediments, nutrients, dissolved organic carbon, pathogens, pesticides, and salt (Bates et al. 2008). Increasing water shortages through competition for scarce water resources from nonagricultural sectors, and the lack of treatment of both domestic sewage and industrial effluents in most developing countries, are likely to exacerbate the problems associated with wastewater irrigation of agricultural products and thus the prevalence of food-borne pathogens. At the same time, the increasing intensification of crop, livestock, and fish production also contributes to adverse water quality outcomes and increased risks related to food safety and emerging zoonotic diseases (Jawahar and Ringler 2009; Otte et al. 2007).

RESPONDING TO MARKET FAILURES

In considering the key entry points for food safety among the poor, it is important to differentiate between market and public mechanisms. and to identify situations with the potential for market failure and a need for a public health driven approach. The two approaches are both essential, to work in tandem to improve food safety for consumers, producers, and other actors along the value chain.

Three factors play a vital role in driving the demands for safe foods: incentives, in the form of consumer pressure for safe food; standards (private or public); and information and awareness among consumers. Implementing standards and monitoring compliance usually imply increased costs, which may act as major constraints to small-scale farmers and others along the value chain, particularly where fixed costs are involved. Where these costs are passed to consumers who are already food insecure, standards may paradoxically exacerbate the problem of access of safe food for those who need it most by “sorting” the market into safe products and cheap products.

Collective action and resource-providing contracts provide a significant means to address these constraints for producers, but these require significant initial inputs and effort to support local capacity, and to establish and maintain the networks and relationships needed to ensure consistent handling practices throughout the entire value chain.

RESPONDING TO GOVERNMENT FAILURES

While private standards are pushing better food standards for produce intended for export and high value markets, these private standards cannot be relied on to ensure the delivery of safe food to poorer consumers in LDCs. The majority of poor consumers and producers in developing countries, particularly in rural areas, are currently not benefited by the changes in agribusinesses that are improving food safety standards. Producers and consumers in developing countries instead must rely on governments that are under-resourced and have limited capacity to monitor for human health risk, much less to support the adoption of risk-mitigation strategies that are appropriate to local conditions, cost-effective, and politically feasible.

Public information on public health and food safety may create premium markets and an added value for those that can ensure the provision of safe food. This would provide an incentive for improving production practices and ensuring the delivery of safe products to consumers that are willing to pay for them. However, food safety must remain essentially a public good, and where markets fail to serve those who cannot afford to pay for safe food, government intervention is essential.

RISK-BASED INTERVENTIONS

There remain huge gaps in our knowledge of the magnitude of health risks in developing countries—and of cost-effective approaches for food-insecure value-chain actors and consumers to mitigate for these risks. Risk-based analysis allows for more nuanced approaches to health risks along the value chain, yielding targeted strategies that take into account political as well as social and economic feasibility, designed to minimize the negative impacts on the health and livelihoods of the poor.

STAKEHOLDER ENGAGEMENT AND THE VALUE-CHAIN APPROACH

Solutions to the problems of food safety and health risks facing the poor in developing countries need to take into account the social, political, and economic realities of the market as well as of stakeholders along the entire value chain. These stakeholders include not only small-scale producers, traders, handlers, importers and exporters, retailers, and consumers, but also international and multinational trade and health institutions and the government institutions responsible for support and oversight of the agrifood industry and public health.

The essential ingredients of a successful approach include: low-cost technologies and methods to reduce health risks, affordable testing for contamination, and a commitment to marketing and dissemination strategies. Solutions must be sought at all levels of the value chain, from reducing risks at the farm level to developing certification procedures at the national and international levels.

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