Traceability and Trade of Genetically Modified Food

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Increasingly variable consumer preferences, rising concerns about food safety, technological advances and diverging national regulatory systems are forcing the global agri-food industry to test a variety of new product-differentiation systems. Consumers, both through their individual purchases and through their representative governments, are demanding more specific and often new product attributes—sometimes related to food safety and at other times related to production and processing methods or non-safety related traits. Meanwhile, biotechnology, in particular, is offering new options for farmers and consumers, as well as putting pressure on existing public and private regulatory systems. Finally, even though primary agriculture was brought under the aegis of the World Trade Organization Agreement in 1995, many governments are slowly, but surely, establishing divergent regulatory hurdles for trade in many of these markets. In a search to sustain or improve operating margins, processors and producers are seeking new ways to differentiate their products to satisfy those diverging demands. It is unclear, so far, whether this effort is coming at a cost that is less than or exceeds the related benefits of satisfying differentiated consumer demand and new technologies.

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In this paper I will:

- discuss the driving forces behind this movement,
- examine how regulatory systems are addressing the challenge,
- outline the extent to which the challenge offers a typology of product-differentiation systems, and
- examine the limited evidence on the costs and benefits of those systems.

Driving Forces For Product Differentiation

The provision of adequate supply and variety of relatively safe, affordable, and nutritious foods to feed a rapidly growing world population and increasingly affluent consumers was one of the key accomplishments of the twentieth century. However, in response to rising standards of living, consumers have increasingly demanded more specific assurances of the safety, provenance, and quality of the foods they consume. This trend became evident shortly after the Second World War and accelerated during the 1990s in response to a series of food-safety failures and introduction of new technologies, especially genetically modified (GM) foodstuffs (particularly corn, soybean, and canola).

Meanwhile, biotechnology is expanding the number of possible types, qualities, and features in our foods. Between 1986 and 1997, biotechnology was used to genetically modify sixty crops for ten different classes of traits. During that period, in excess of 25,000 field trials were conducted in more than forty-five countries (James, 1997). As of 2002, sixteen crops modified for one or more of forty-seven phenotypic traits were commercialized, most with attributes related to input and yield performance. Insect resistance (*e.g. Bt* cotton and corn) and herbicide tolerance (*e.g.* Roundup Ready® soybean, corn and canola), as single or stacked constructs, accounted for 99% of the GM world acreage in 2002. Plants have also been engineered to resist viruses (*e.g.* NewLeaf™ potato) and to be sterile (*e.g.* the InVigor® hybrid system for canola). Over the first eight years of commercial cultivation, those fifteen crops were planted on an estimated 240 million hectares. There also has been an effort to develop and commercialize output trait crops, including delayed ripening tomatoes (*i.e.* FlavrSavr™), new or modified oils (*e.g.* Laurical® canola) and blue carnations. Industry reports that many more are expected in the near future. Finally, there is a push to use the global agri-food system as the base for bioengineered industrial products (such as producing industrial enzymes and oils) and to produce pharmaceutical proteins in plants; between 1990 and 2003, the United States authorized sixty-two field trials for plant pharmaceuticals while Canada approved fifty-two.

Meanwhile, the trade imperative has been rising. While sixteen countries have produced one or more transgenic crops, the United States, Argentina, Canada, and China accounted for 99% of the acreage over the first eight years of production (James, 2002). With GM production concentrated in those key exporting countries, a wide range of markets are now affected. Table 1 shows

TABLE 1. DISTRIBUTION OF PRODUCTION AND TRADE IN GENETICALLY MODIFIED FOOD CROPS, 2002.

[adapted and updated from Phillips (2002) using James (various) and FAO (2000)]

	Total world production (2002)		Production in countries producing approved GM varieties (2002)		Exports (2001)	Imports (2001)
Commodity	# Countries	Volume (Mt)	Country	% total	% total world exports originating in countries with GM prod'n	Total # countries importing commodities
Canola	53	33.1	Canada, USA	13%	45%	70
Cotton	85	33.2	Argentina, Australia, China, Honduras, India, Mexico, South Africa, USA	59%	67%	57
Maize	160	603	Argentina, Canada, France, Portugal, Philippines, Spain, South Africa, USA	48%	85%	181
Melon	13	0.6	USA	0%	0%	10
Papaya	51	5.9	USA	<1%	<1%	77
Potato	154	307	Canada, Ukraine, USA	14%	9%	190
Rice	114	576	USA	2%	10%	195
Soybean	84	180	Argentina, Canada, Romania, USA	59%	65%	128
Squash	88	16.9	USA	4%	0%	38
Sugar beet	52	247	USA	10%	3%	34
Tobacco	129	6.3	China, USA	44%	16%	195
Tomato	162	109	USA*	11%	5%	148

NOTES: GM flax was approved in Canada and the United States, but never commercialized. *Records are inadequate to determine whether GM tomatoes are being grown in four other countries. Other minor crops approved in the United States include chicory, cantaloupe and radish.

that 85% of trade in some products comes from GM producers (although GM produce does not represent 100% of their sales) and as many as 195 countries could be importing GMOs.

DOMESTIC AND INTERNATIONAL REGULATION OF FOOD SAFETY

In the past, new food products that were reviewed and approved in the country of production were generally granted unrestricted access to global markets. Rising consumer concerns about food safety and widely varying citizen concerns about environmental, social, economic, and ethical aspects of GM

foods have led many countries to change their practices and require a domestic review of food products before they can be imported or sold to local consumers. Governments in most exporting and importing countries acknowledge that these national reviews could adversely affect the free flow of trade in food products. As a result, there has been renewed international effort to find a means of redesigning the multilateral trade system to more comprehensively assess and manage food-safety risks. In effect, each of the institutions is attempting to create greater consensus about how to manage such risks.

National governments have responded to these pressures in a variety of ways. While many of the individual government measures (such as reviews of efficacy and safety of GM products and differential labeling rules) may have been implemented for legitimate objectives, the result has been diverging regulatory hurdles for trade in many of these markets. Different countries now require different levels of assurance that the products they are importing do not involve certain production processes, such as GM traits. These new hurdles are not only higher, but differ between markets, requiring greater specificity in shipments to international markets.

The main visible manifestation of these different views is the diverging rules related to labeling GM foods. The ultimate challenge is to provide a credible, transparent, and accountable system that provides effective choice to consumers between GM and non-GM foods. While the principle is simple, and most governments agree with it, many difficulties are involved in delivery. Given the credence nature of these markets—*i.e.* claims are not testable by consumers directly—most companies have been unwilling to voluntarily label their products. Thus, the debate has moved to the regulatory systems around the world. As of 2002, more than twenty-six countries had either adopted provisions or announced plans for rules to assist the market to develop and deliver labeled products. At one extreme, regulators in the United States, Canada, Argentina, and Hong Kong have concluded that mandatory labels will be required only to signal known public-health and safety aspects, such as nutritional and compositional changes or new allergens. Food processors may use voluntary labels in those markets to signal that their product includes either GM traits or that it is free of GM traits, provided the claims are credible and verifiable. At the other extreme, twenty-two countries, plus the European Union (EU), have adopted or announced plans to implement mandatory labeling systems, with a range of thresholds for co-mingling(*e.g.* 1%, 3%, 4%, or 5% by volume of ingredient). While mandatory labels seem to address consumers' concerns, they are far from a perfect solution. A variety of studies suggests that labeling systems could impose a one-time set-up cost of 1 to 6% of annual food expenditures and an on-going cost of 0.5 to 3%. Given that there is no strong public-health rationale, and that only a minority of consumers state, or show in experiments, that they would pay for GM-free or proactively-labeled GM products, there is some question about whether mandatory labels are

TABLE 2. THE CURRENT ARRAY OF INSTITUTIONS REGULATING INTERNATIONAL TRADE IN GM CROPS.

(adapted from Phillips, 2002)

Institution	Date	Coverage	Member states	DSM*	Orientation
International Office of Epizootics (OIE)	1924	Infectious animal diseases	155	Non-binding; sets WTO standards via SPS S.3.4	Harmonize import and export regulations for animals and animal products through International Animal Health Code
Food and Agriculture Organization	1945	Food security	184	None	Establish policy statements and convene expert groups
International Plant Protection Convention (IPPC)	1952	Pests and pathogens of plants and plant products	107	Non-binding; sets WTO standards via SPS S.3.4	International Standard for Plant Measures (ISPMs) involving quarantines
World Health Organization	1954	World health	192	None	Establish policy statements and convene expert groups
The Codex Alimentarius Commission (Codex)	1962	Food labeling and safety standards	165	Non-binding; sets WTO standards via SPS S.3.4	international standards to provide guidance to the food industry and protection to consumer health
OECD	1969	Harmonization of international regulatory requirements, standards and policies	29	None	Consensus documents
Regional initiatives	1990s	Harmonization of the science of regulation	Various	None	Regional side agreements, MOU, MRA, formal dialogues, and joint research projects
WTO	1995	Trade in all goods and most services	138	Binding	Establish rules for transparency and dispute settlement through TBT and SPS agreements
BioSafety Protocol (BSP)	2000?	Transboundary movements of living modified organisms	63 signed	None	Will require advanced informed agreement for first shipments of LMOs intended for deliberate release; commodity shipments to be notified

*Dispute-settlement mechanism.

efficient. A recent development is the plans by the EU to replace its system of labeling only for detectable proteins with one that requires full labeling of all foods produced using transgenic technologies, which will require a full traceback system to operate, both in the EU and in exporting markets (European Union, 2001).

The recent trade challenge to the EU has signaled a new phase in the debate about regulation of GM foods. On May 13, 2003, the governments of the United States, Canada, Argentina, and Egypt announced that they would be filing a complaint with the World Trade Organization on the grounds that a *de facto* EU moratorium on new GM foods violates international trade law. Their position is that the moratorium on the approval of GMOs is inconsistent with WTO rules and that the moratorium is not based on scientific risk assessments and, therefore, creates an unjustified barrier to trade. Other countries that have since expressed support for the filing of this case include Australia, Chile, Colombia, El Salvador, Honduras, Mexico, New Zealand, Peru, and Uruguay. Nine international bodies have been working to coordinate and regulate different aspects of food safety (Table 2). Conceptually they represent a progression from institutions that are largely science-based (IPPC, OIE, Codex, WHO), one trade-based (WTO) and others that have broader objectives, such as environmental protection and other social and political goals (OECD, FAO, regional initiatives and BSP). A more detailed analysis of these institutions and their roles is available in Phillips (2002).

Suffice it to say that these nine institutions are working to develop rules to ensure health and environmental sustainability while, at the same time, supporting international trade. To that end, they are individually (and occasionally collectively) undertaking efforts to develop standards for safety and evaluation, to develop scientifically defensible testing procedures and to develop rules to ensure consistency where possible. They also offer dispute-settlement processes or mechanisms to handle any disagreements.

The difficulty with the evolution of the combined national-international regulatory systems is that while some progress is being made in some areas on technical matters, none of the international effort is designed to deal with many of the challenges posed by new technologies. Consumer concerns, ethical considerations, and various socio-economic factors do not fit within any of the institutions. In absence of any consensus on those and other issues, national regulatory systems will continue to diverge. As a result, the GM agri-food community will continue to face a "patchwork" of regulations, with national systems providing basic, but different, standards and international bodies setting minimum, but potentially unenforceable, standards for different aspects of the regulation of products of biotechnology. At root, national governments do not have enough confidence in each other to accept a trading partner's system. For the time being, the agri-food market will continue to face that uncertainty.

The structure of the global commodity production and marketing system

A compounding problem for consumers, industry and the regulators is that the global agri-food system is highly integrated, with more than 340 million tonnes of bulk cereals and oilseeds traded in 2001. The global commodity trade system—the current target for GM varieties—is fundamentally designed to deliver consistent quality at competitive costs and prices, which has led to extensive standardization, blending, and pooling to either create uniform quality or to lower transportation and handling costs. I will use Canada's system to illustrate this point.

In Canada, the research community, both indigenous and foreign-controlled, annually produces, on average, thirty new canola varieties, fifteen wheat and durum varieties, ten barley cultivars, and five pea varieties. Once approved for release, seeds of these cultivars are multiplied for sale. Farmers purchase different shares of their seeds for different crops. Canola producers buy, on average, 90% of the seed they need annually, while wheat, durum, barley, and pea farmers buy only about 40%. This seed is produced by more than 3,000 registered and certified seed growers in Canada. Annually, approximately 250,000 Western Canadian farmers plant 50 million acres of these five crops, generally in 80- to 160-acre fields, each of which yields between 2,400 and 8,200 bushels, depending on the crop and area harvested. Producers harvest the seed usually within a 1-month period in the fall, using mostly owned or leased equipment and family or hired labour, and then store their grain on-farm in bins that range in size from 1,500 to 4,200 bushels.

Grains or oilseeds for export are called forward through quotas by the Canadian Wheat Board (for wheat, durum, and malt barley) or under contracted conditions or spot market offers by the private grain trade (for canola and peas). Farmers deliver about half their grain themselves in trucks that haul 300 to 350 bushels, while about half the crop is moved in commercial trucks that hold between 25 and 42 tonnes, equal to 900 to 2,000 bushels. More than 80% of the delivered grain is elevated either in a primary elevator (on average with forty-four bins each holding between 45 and 120 tonnes, equal to one to five commercial truck loads or fifteen farm-grain trucks) or in an inland terminal (each with bins holding between 160 and 700 tonnes, the smallest of which could hold twenty farm-truck deliveries or four to six loads from commercial trucks). The bulk of that grain is then transported to port on rail hopper cars of 90 tonnes capacity (equal to one to two bins from an average country elevator or a fraction of a bin in an inland terminal), usually in 125-car unit trains . At port, the grain is offloaded, sorted into large terminal bins and, finally, loaded onto ships with holds averaging 5,000 to 6,000 tonnes, destined for one of 120 foreign markets.

Clearly, the system goes from the smallest and most discrete scale at the seed-development stage to a highly aggregated and blended system when exported.

This blending is done both to ensure the most consistent quality within and between shipments and to drive marketing and distribution to the lowest unit cost. One difficulty is that the large number of physical transfers and the high amount of blending increases the risk that crops will be co-mingled with other elements that could lower the quality. Historically, this has been handled by rigorous regulations, based on visual identification, that have limited the potential for unintended or deliberate co-mingling. This has been matched by extensive quality assurance by the private grain trade. With the introduction of GM varieties, however, visual identification is no longer easy. The regulatory and marketing systems are going to be forced to adjust.

A Typology of Product Differentiation

Firms facing the combination of consumer demands for differentiation, increasingly specialized technologies and products, and diverging regulatory systems have resorted to seeking new ways to differentiate their products in the market. The definition of product differentiation can have several nuances, depending on the justification for the differentiation. Frequently the terms "identity-preserved production and marketing," "segregation," and "traceability" are used interchangeably in the supply-chain literature. This is creating misconceptions about the distinct role that each of these product-differentiation systems has in the supply of food products. The purpose of this section is to delineate the three systems, identify the features that are both unique and common and to identify the relative costs and benefits of each system (Table 3)[2].

Identity Preservation

The first system involves identity-preserved production and marketing (IPPM), which is initiated by private firms in the food industry to extract premiums from a marketplace that has expressed a willingness to pay for an identifiable and marketable product trait or feature. An IPPM system is a "closed loop" channel that facilitates the production and delivery of an assured quality by allowing identification of a commodity from the germplasm or breeding stock to the processed product on a retail shelf (Buckwell *et al.*, 1999; Lin, 2002).

The objective of an IPPM system is revenue-management. Premiums need to be available to attract participants and the efforts of participants will be directed towards capturing a share of the premium. Participation in these systems is voluntary. The lead stakeholders in IPPM systems are private firms seeking to capture the increased value of special traits. The role of the regulatory body is to ensure that industry standards are handled in such a way as to prevent consumer fraud. The information may be asymmetric, as only the product seller

[2]See Smyth and Phillips (2003) for more discussion of this typology.

TABLE 3. COMPARING IDENTITY PRESERVATION, SEGREGATION AND TRACEABILITY.

(adapted from Smyth and Phillips, 2003)

Component	IPPM	Segregation	Traceability
Overall management			
Objective	Revenue management	Product safety	Liability management
Status	Voluntary	Mandatory	Voluntary or mandatory
Lead stakeholder	Private company	Regulator	Commodity group, standards organization or regulator
Information flow	One or two way	One-way	Two-way
Supply chain focus	Downstream	Downstream	Upstream
Testing/auditing	2nd party/brand owner	1st party/regulator	3rd party/standards organization
Production-stage features			
Production arrangements	Formal production contracts	Regulation and contracts	Membership in quality standard
Production controls	In-season agronomic rules vary with product	Formal buffer zones; post production land use controls	Process standards adopted and record keeping
Processing-stage features			
Enforcement	Private	Public	Collective
Quality criteria based on	Product standards	Regs or HACCP	Processes (*e.g.* ISO)
Tolerance levels	Variable	Set in law	Performance based
Testing/auditing	2nd party	1st party	3rd party
Retail-stage features			
Provides access to	Branded product market	Markets	Product categories
Information provided to	Consumer	Regulator	Regulator, retailer or processor
Penalties for failure in product market	Consumer fraud charges; lost brand value	Criminal prosecution; mandated product recalls	Consumer fraud charges; exclusion from product category
Price premium	Yes	None	None
Labeling	Private brands	None	Quality standard

can know with certainty what level, if any, of cheating has occurred in the delivery of the product. Moral hazard may be present due to the presence of premiums. Effective IPPM systems that span entire supply chains must have accurate two-way flows of information. This means that information about purity and quality of the product flows downstream and information coming from consumers must flow upstream. While the information flow in IPPM systems is two-way, the focus of the system is downstream. Each participant in the system wants to ensure they extract a portion of the value of the special trait, whether from production, processing or retailing the product. This means that each participant will focus on the needs of the next participant in the supply chain. Market failure can result in fraud charges for improper labeling and create awareness among consumers that certain brand names cannot be trusted. Second parties acting on behalf of the brand owner or developer of the special trait will usually do the testing and auditing.

Numerous IPPM systems are operating around the world. Some involve only the breeders and the wholesale market or processor, while others extend to the retailer. Their structure depends on the attribute they are trying to preserve. Some novel oils, such as low linolenic oils that are more stable in fryers, have value only at the processing level while others, such as high oleic oils, have health attributes that can be marketed to consumers. Identity-preserved production and marketing systems are important for providing information to consumers about the provenance of a product, as those attributes are not visible or detectable in the product itself. A number of IPPM systems operate in North America. While organic products are perhaps the most noticeable IPPM products, Cargill has an IPPM system in place to export canola to Japan (the variety gives off virtually no odor when used to fry food), General Mills operates an IPPM system for a select variety of white wheat that possesses a special trait for "flake curling" when processed into breakfast cereal, and Dow AgroSciences uses an IPPM system to export the Nexera canola variety to Japan where it is sold into the specialty gift oil market. In each of these systems, there are a range of costs and benefits. Essentially, the systems must generate adequate premiums in the intermediate or final markets to justify the added costs. The market actually determines the value of the systems, by revealing what tolerance for off-types it will allow (which sets the benchmark for costs) and then revealing the incremental premium for the differentiated trait. A number of systems studied have been calculated to have incremental costs (over the commodity system) of US$20 to 35/tonne, and by assumption their continued operation implies that the premiums must exceed those levels.

Segregation

The second product-differentiation system is segregation, which Lin (2002) defined as the requirement "that crops be kept separate to avoid co-mingling during planting, harvesting, loading and unloading, storage, and transport."

Segregation systems are used when potential food-safety concerns exist over the co-mingling of the segregated product and all other like products. In short, IPPM systems are used to capture premiums and segregation is used to ensure food safety. Participation is not optional—any producer or firm involved with segregated products will have to comply with standards that have been approved by the regulatory agency. The private firm will have the responsibility of developing the actual system, but the regulatory agency will be the final arbiter on approving the system for field use. The focus of product delivery within a segregation supply chain will be downstream. Segregated commodities commonly have industrial value, so these products will be supplied to meet the criteria of the processor. Product failure would most definitely see a complete recall of any products suspected of being affected and could result in criminal prosecution in the most severe instances. Testing and auditing will be vital features of segregation systems and will be conducted by agents of, or acting on behalf of, the regulator. This process will also reinforce the level of trust with foreign export markets.

Very few open-field crop-segregation systems presently operate in the global agri-food system. All industrial and pharmaceutical crops would require segregation. The best-known segregation system in Canada is for high erucic acid rapeseed (HEAR), which has industrial value due to the high acid content—eleven HEAR varieties are currently under cultivation in Canada. Two varieties of transgenic, novel oil canola (Calgene's Laurical® varieties) were contract registered and produced between 1996 and 1999, and a small amount of *Brassica juncea* was segregated for the first time in 2002. All plant-made pharmaceutical trials require full segregation. As one would expect with these types of systems, there is no tolerance for co-mingling. As such, the costs have tended to be higher, and by implication, the premiums must be higher. High erucic acid rapeseed earns, on average, a $60/tonne premium in Canada and unsubstantiated reports peg premiums at well over $100/tonne for other specialty industrial and pharmaceutical crops.

Traceability

The third product-differentiation system is traceability. The International Organization for Standardization (ISO) has defined traceability as the "ability to trace the history, application or location of an entity by means of recorded identifications," and the Codex Alimentarius Commission has adopted this as their working definition for all Codex standards (Codex, 2001). Traceability systems are designed to ensure that products available for consumption are as safe as possible. Participation in a traceability system can be voluntary, depending on where in the supply chain the participant is located. The closer the participant is to the start of the supply chain, the more likely it will be that participation is voluntary. The lead stakeholder may be a commodity group demanding greater clarity in, or selection of, food products, a standards council

that comprises industry representatives from all sectors of the supply chain or the regulator seeking to ensure consumer protection. Traceability systems have information flowing two ways, as these systems are designed to react quickly to food-safety concerns. If a product is discovered to exceed any defined tolerance level at any point in the supply chain, traceability will be used to identify the source of the problem and to locate any and all retail products that may be affected. Information on food safety flows upstream while information on specific products flows downstream. This results in the focus of traceability systems being upstream. Market failures can also result in consumer fraud charges in addition to permanent exclusion from selling into that supply chain. Testing and auditing will be conducted according to standards developed by third-party organizations.

Increasing numbers of traceability systems are operating. Perhaps the oldest and most-developed is the manufacturer's lot number system that traces processed foods from plants to consumers. Those were implemented largely to handle liability of contaminated foods. More recently, retail chains in the United Kingdom adopted extensive traceability systems (from retailer to farmer), initially for beef but now for a growing list of products, in order to manage liabilities flowing from the UK Food Safety Act, 1990. More recently, the livestock industries in twenty-five countries have either introduced or announced plans to introduce partial traceback systems (from slaughter house to birth), and there has been significant discussion about if and how a traceback system can be developed for commodity grains and oilseeds. While these systems, which add between 1 to 5% to the cost of a product, do not add any directly identifiable premium to the product, they do act as a form of insurance against a food contamination that could cause the recall of an entire product category. The recent detection of bovine spongiform encephalopathy in a Canadian cattle herd is estimated to have cost the industry $11 million/day. The incomplete traceback system operated by the Canadian Cattle Identification Agency will have paid for itself if it can reduce the trade embargo by even a few days. Even though no traceback provisions exist for GM foods yet, the EU has proposed in its latest set of rules that its modified labeling rules would need to be backed up by a traceback system both within the EU and in the exporting countries, in order to validate claims of GM or GM-free status in products without detectable recombinant DNA (EU, 2001). This would be a novel use of traceback, as no other systems operating are imposed by the state—all of the others are economic choices adopted by potentially liable firms seeking to limit their exposure to losses.

Conclusions and Observations on the Way Ahead

Global agri-food markets, and especially markets for GM foods, are at a crossroads. It is probably fair to assume that consumers will not be any less demanding in the coming years, or that technology will stop advancing. The

real uncertainties relate to how regulators and industry will manage the two trends. There would appear to be three possible futures.

The pessimistic future might be that technologies swamp the capacities of consumers and regulators to assess, test, and adopt new products. In that case, everyone will be playing catch-up, which would create the conditions for individual national governments to attempt to handle their own problems by erecting even higher or more impermeable barriers to trade. This would be disastrous, as the global agri-food system depends critically on trade, and many nations around the world require trade to assure the appropriate quantities or varieties of food to meet their domestic needs.

The alternative, optimistic outcome might be for regulators to come together, either through negotiation or litigation, and adopt common standards, testing protocols, and regulatory processes that can effectively and efficiently deliver consistent and timely decisions in all key markets. This would not be impossible to achieve, but is unlikely given current government trajectories.

Finally, the most likely outcome would involve us muddling through, with industrial organizational reforms just about keeping ahead of the pressures for product differentiation coming from consumers, the technology, and regulators. To some extent, this would be like moving along the hogback of a steep hill—one small deviation either side would tip the sector into a new direction.

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