Volume 18 Number 2 2017/pp.63-77 www.usask.ca/esteyjournal

The Estey

Journal of International Law and Trade Policy

# Genomics, International Trade and Food Security

William A. Kerr
*Associate Member, College of Law, University of Saskatchewan, Canada*

Genomic information and its associated technologies appear to have the potential to significantly increase agricultural productivity and, hence, contribute to meeting the food security challenges that feeding nine billion people by 2050 presents. The costs of genomic information and the associated implementation technologies continue to fall. Much of the output of genomic-based improvement may not qualify for protection as intellectual property. It also does not suffer from the concerns that have been associated with transgenic technology – GMOs – such as potential risks to human health and the environment, ethical issues and highly concentrated control of the food system. As a result, both the regulatory and trade regimes need not be as rigorous as has been the case for GMOs in some jurisdictions. A regulatory regime that encourages investment in genomics-based agricultural technology and an open trade regime will facilitate the ability of the technology to contribute to global food security.

Keywords: agricultural productivity, food security, genomics, international trade, regulation

> Looking ahead, genomic techniques have strong potential as one of the key technologies to offer solutions, accelerating our ability to develop varieties with characteristics of drought, heat and saline resistance, as well as resistance to pests and disease ….
>
> John Beddington
> Chief Scientific Advisor to the UK Government, 2010

Technological progress and international food trade are inescapably intertwined in the struggle to improve global food security. One of the major threats to food security is rising global food demand. This has two components: (1) the projected rise in global population from approximately 6.8 billion people in 2017 to 9 billion in 2050, and (2) increasing incomes in major developing markets such as China, India and Indonesia. Meeting the needs associated with the increase in population alone will require an increase in global food production of approximately one-third in less than 35 years. As incomes rise out of extreme poverty (i.e., from US$1.00 or US$2.00 per day to US$10.00 per day), most of that extra income is spent on food. The combination of these two forces is projected to double food demand by 2050. If agricultural productivity does not increase sufficiently to meet this increase in demand, the food security of some – likely the world's poorest – will deteriorate.

International trade is directly important for food security because most of the increase in global population will take place in developing countries, where agricultural production is currently often conducted in an unsustainable fashion and where the negative effects of climate change are likely to be most severe. Local production cannot simply be increased sufficiently to meet the increase in demand. Hence, if food security is not to decline, additional food must be obtained through international trade from net–food exporting countries. This is international trade's direct contribution to enhancing food security (Smyth et al., 2017).

There is also a way that international trade makes an indirect contribution to food security through increasing the potential market size for those investing in new technology (Kerr and Yampoin, 2000). This is important because expected market size is central to the decision process of firms engaging in research and development. Positive investment decisions will be made when the discounted future expected benefits exceed the discounted expected costs. The greater the expected size of the market the larger will be the expected benefits from making an investment. Trade barriers restrict access to markets and, thus, reduce the size of the expected benefits arising from an investment. The result is that the rate of investment in research and development is reduced (Smyth et al., 2011). Reduced investment in research and development slows the rate of productivity improvements. If the rate of productivity improvement slows, it will be difficult to increase agricultural output to meet the food security challenges that will arise in the run-up to 2050.

While the relationship between expenditures on research and development in agriculture and increases in agricultural productivity is not deterministic, the correlation is strong and positive – but there is always the risk that any particular research and development project will not succeed. At a time when food demand is expected to increase significantly, the rate of productivity increase in agriculture has been declining (Alston, 2010). While increasing productivity is not the only way to meet the increasing demand for food, alternatives such as reducing post-harvest losses and other forms of food waste can have only a limited impact on improving food security. Increasing agricultural productivity has been at the heart of escaping the Malthusian trap (Malthus, 1798) over the last two centuries. Thus, anything that systemically reduces the rate of technological progress in agriculture requires careful investigation (Smyth et al., 2015a).

One such constraint on the rate of technological improvement in agriculture has been the international controversy over the use of transgenic technology – or genetically modified organisms (GMOs) – in agricultural production. The productivity-enhancing potential of GMOs has been understood since the inception of the technology (Marks et al., 1992; Marks et al., 1995) and, where its use has been approved, has considerably improved productivity in agriculture (Smyth et al., 2015b).

Whether it is appropriate to use GMOs in agriculture has been endlessly debated since the technology reached the stage of potential commercialization (Hobbs et al., 1990; Perdikis, 2000; Gaisford et al., 2001; Isaac et al., 2002; Hobbs et al., 2005; Isaac, 2007; Clark et al., 2014; Smyth et al., 2016). Regardless of the merits of arguments pertaining to the use of GMOs in agricultural production, no international consensus has been reached, and global markets are bifurcated into countries that accept the technology and those that do not. A number of countries, including the United States, have embraced the technology, permitting production and human consumption of agri-food products derived from the use of GMOs. On the other hand, a number of countries, and the European Union in particular, have eschewed[1] the use of the technology in production and in the human consumption market.[2] Common ground on biotechnology has remained elusive (Isaac and Kerr, 2007; Kerr, 2016a).

Countries that have not accepted the use of the technology impose trade barriers – often import bans on products which have been produced using the technology (Viju et al., 2014; Kerr, 2015). In addition, there is the problem of unintended mingling (often called co-mingling) of trace amounts of GMOs that have not been approved by importing countries in non-GMO export shipments. The result is the rejection of the load at point of import and disruptions to trade (Hobbs et al., 2014). The problem has been growing because asynchronous approvals among countries are increasing as more and more GM-crops are approved in those countries that have accepted the technology (Kerr, 2016b). The import bans and rejection of international shipments due to co-mingling are the direct effects of the difference in the acceptance of GMOs among countries. It means that consumers in countries not allowing the import of products derived from GM technology forgo the benefits of lower cost GM products.

A second effect of the disagreement over the appropriateness of GM technology is the loss of the benefits available from GM technology for developing countries that do not adopt the technology for fear of losing export markets in developed, but non adopting, countries. This has been particularly important for a number of African countries that have export markets in the EU (Smyth et al., 2013; Paarlberg, 2014). The result is that African farmers lose access to a productivity-enhancing technology and consumers in both Africa and the EU pay higher prices for African-sourced food.

The indirect effect of the trade issues surrounding GM foods, however, may be more detrimental to food security in the long run than the direct effects. Having a significant proportion of the global market eschewing acceptance of GM technology and products means that the potential market for those investing in the research and development of new GM products is smaller than it could be. This feeds back into the decisions of the firms contemplating those investments. As the potential benefits are reduced, fewer avenues for research will exhibit the potential for positive returns on investment and, hence, will be funded (Kerr and Yampoin, 2000). As a result, the rate of increase in agricultural productivity is reduced. As suggested above, future food security depends on improvements to agricultural productivity.

In some cases, the decline in the size of potential markets for individual crops arising from the failure to accept GM technology has led to the abandonment of all attempts to commercialize GM varieties of the crops. The most obvious example is wheat (Furtan et al., 2003; Wilson, 2014). GM flax was developed in Canada and licensed for commercial production in both Canada and the United States but was subsequently withdrawn prior to commercialization due to concerns over potential EU import bans (Viju et al., 2014). Other crops include tomatoes and potatoes (Ryan and McHughen, 2014). The total effect on investment in research and development of new GM crops is unknown, as it involves the investment decisions of private firms, but it is likely to have been substantial (Pavleska, 2017). The effect has been particularly investment inhibiting for crops which are largely grown in developing countries –

often tropical crops – where there has been very limited investment (Perdikis et al., 2004).[3]

When transgenic technology was still in the early stages of commercialization, it was believed that it had tremendous potential to increase agricultural productivity and provide foods that contained additional or enhanced attributes that would be desired by consumers (Gaisford et al., 2001; Klein et al., 1998). The controversy that has surrounded GMOs, almost since the onset of commercial production, and the trade barriers that have followed it, have meant that the actual impact of such crops has been much reduced and a major opportunity forgone. This unfulfilled potential is often overlooked when the very large acreages where GM crops have been adopted are discussed. The forgone potential is due not only to the restricted geographic extent of the use of the technology but also to the limited number of crops where it has been applied. Today, genomics is at roughly the stage GM technology was at its point of first commercialization, where expectations pertaining to its potential were very high. Thus the important question is whether genomics will suffer a similar fate to GMOs, or will the international regulatory and trade systems allow this new technology to reach its full potential to assist in achieving food security goals over the near future?

Genomics relates largely to using information that is becoming available from gene sequencing and associated technologies to improve the production performance of, or enhance valued attributes in, plants, animals or other organisms. While genomic information can be used to increase the efficacy of development of transgenic crops, it also has widespread uses in crop improvements that do not involve transgenic processes. It uses genetic information to more accurately determine the pathways used in devising plant improvement strategies – removing much of the trial and error associated with traditional selection methods used in conventional (non transgenic) plant breeding (Araki and Ishii, 2015). According to Hartung and Schiemann (2014, 750),

> The growing number of crop genetic improvement technologies accompanied by elaborate transient transfer and expression techniques, as well as modern concepts such as synthetic genomics or reverse breeding, aided by sophisticated high-throughput analytical techniques, provides a set of superior tools to quickly and precisely alter the genomic sequences of plants. Using these techniques, potential adverse effects are even less likely than in conventional transgenic plants or plants resulting from conventional breeding. The combination of various new techniques will allow precise genetic modification, resulting in plants that harbour as little recombinant DNA as possible or none at all.

New technologies are also developing that greatly reduce the costs to plant breeders that wish to act on the genetic information that is increasingly available. One such technique is CRISPR.[4] According to the *Western Producer* (2015),

> Most GM crops were developed with transgenic techniques, or genes from other species, to achieve a trait such as insect resistance in corn or a canola plant with herbicide tolerance. Genome editing is not transgenic. Instead, biologists use what is usually described as “molecular scissors” to alter a gene in a plant’s DNA without introducing foreign genes. The technology has been around for a while, but the established techniques were cumbersome and expensive. In 2012, scientists unveiled a new method, called CRISPR/Cas9, to precisely cut and paste a gene in a plant’s genome…. The CRISPR technology is particularly exciting because it’s efficient, versatile and relatively inexpensive. Its low cost may permit university and government scientists to quickly develop useful crop traits such as disease resistance in wheat or improved oil content in sunflowers.

Thus, it would appear that the use of genomics in plant breeding has the potential to increase agricultural productivity without resorting to transgenic methods. As a result, there may be no need to subject it to the much stricter regulatory regime and international trade regulations that have been imposed on GMOs in a number of countries.

The regulatory issues surrounding GMOs were relatively unique in that resistance to the technology brought together in common cause four relatively distinct groups in society that often have strong preferences: (1) those already concerned with the safety/quality of the food they were consuming (e.g., organic production, hormones in beef, antibiotic resistance); (2) those concerned about the environment; (3) those who were concerned about the ethics surrounding the use of the technology (e.g., messing with God’s work, because genes do not move naturally between species); and (4) those concerned with the influence large, multinational agribusiness firms could have on the food system (Gaisford et al., 2001; Kerr, 2001). Latterly, those such as the organic industry, which can be seen as having more traditional *vested interests*, became involved in the anti-GM fray (Clark, 2015; Smyth et al., 2015c).

The major concern of those opposed to transgenic technology on the basis of food safety concerns was any potential risk associated with ingesting transgenic products over the long run. The existing regulatory regimes were perceived as able to ensure that short-run hazards such as allergenicity did not arise, but the concern was that there was not sufficient scientific information regarding the long-run effects of foods with new genetic combinations to know if the risks pertaining to human health were at acceptable levels. For those with this concern, having GM products in the market was unacceptable, particularly if they were not labeled (Hobbs and Kerr, 2006).

If genomic information and associated techniques are not used to produce transgenic food crops, then the concerns over the genetic composition of food products should not apply. In terms of the genetic material involved, the food safety implications should be no different than with food products arising from conventional breeding.

Environmental NGOs' concerns pertaining to GMOs were that their release into the natural environment had the potential to lead to externalities that have a negative impact. Given the absence of complete scientific certainty related to how organisms with new gene combinations interact with organisms in the natural environment, the risks of these adverse impacts, some of which could be irreversible, were simply perceived to be too great (Van den Belt, 2003; Hobbs and Kerr, 2005). The potential for the transfer of disease resistant traits to weeds, thus creating *super weeds,* and the potential lethal effects on Monarch butterfly populations are examples of such *speculative risks* (Isaac, 2007).

Genomics and its associated techniques should not raise the issues pertaining to risks to the environment that arose in the case of transgenic crops. Of course, any new crop needs to be assessed for its ability to fit into the environment, but there is no need for a special regulatory regime, nor for special international trade rules such as those associated with the creation of plants with transgenic gene combinations.

Nor should the use of genomic information to improve plant varieties raise the same ethical issues as GMOs. Of course, some of the broader ethical issues remain, as the new information and associated technologies may have applications in, for example, human genetics. Thus, there may be those who have ethical concerns related to genomics, but not specifically to its application to plant breeding.

In terms of the concerns with the influence that large, multinational agribusiness firms can have on the food system, genomics may have considerable implications. Traditionally, plant breeding was largely done in public institutions such as universities and government agricultural research stations. This was because of the inability of private sector investors to recoup the research and development costs of developing new plant varieties because, once a crop was commercialized, farmers adopting the variety could simply retain a portion of the crop to be used as seed the following season – meaning there was no need to purchase seeds in subsequent years (Buckland, 2004).[5] Without the prospect of multi-year sales it is difficult to obtain a positive return on a private investment in plant breeding. Further, the patenting of living organisms was not sanctioned.[6]

In the 1980s, when biotechnology and transgenic methods were coming to the fore, governments perceived that the technology was going to require very large outlays for research if it was to reach its potential – expenditures they were unwilling to shoulder. An alternative had to be found. The key to bringing forth investment from the private sector to fund research and development in biotechnology was to extend intellectual property rights to include aspects of living organisms (Kerr and Isaac, 2005). The required changes to intellectual property laws were made both domestically in most modern market economies and in international law (Kerr et al., 1999).

Initially, the extension of intellectual property rights to cover the methods and the outcomes of investments in modern agricultural biotechnology brought forth a plethora of start-ups funded by venture capital as well as investments by existing large agribusiness firms such as Monsanto, DuPont and Novartis (Gaisford et al., 2001). Over time, however, given the high cost and long lags associated with receiving regulatory approval (Smyth et al., 2016; Phillipson and Smyth, 2016), the industry became increasing concentrated in the hands of the large agribusiness firms. Further concentration followed through a spate of mergers and acquisitions among these large firms – a process that is ongoing (Hobbs, 2014). This concentration of control over genetic inputs for the major GM crops – soybeans, corn, canola – is one of the longstanding concerns of those who have opposed GMOs. It has been an issue in both developed and developing countries (Cardwell and Kerr, 2008).

The *double edged sword,* as Richard Gray (2017) describes it – the need to protect intellectual property to provide the incentive for firms to make the investments in research and development, which results in monopoly, reduced quantities and elevated prices over the time intellectual property protection is granted – is a well known trade-off (Perdikis et al., 2004). In the case of GMOs, given their association with food production and food security, critics argue that the costs of monopoly outweigh the technological benefits (Buckland, 2004).

Genomics and its associated technologies are at the stage transgenic technology was prior to commercialization. At this point the cost of genomic information and technologies such as CRISPR are sufficiently low (and continuing to decline) that they do not represent a significant barrier to entry – suggesting the potential for considerable competition. Further, a considerable proportion of the outputs of those using genomic information (though not all) would not currently qualify to receive protection as intellectual property in the same way as GMOs. There is also no reason that applications arising from the use of genomics would not germinate if a proportion of a crop were to be saved by a farmer for seed. With low-cost competition and considerably reduced opportunities for multi-year sales, large multinational agribusiness firms may not see sufficient rewards to invest in developing the technology. As a result, a genomics-based seed supply industry would look more like the one that existed prior to the advent of GMOs. The new varieties would come from smaller private plant breeding firms or the public sector, including universities. Richard Gray (2017) suggests another source of investment in genomic-based plant breeding: producer groups. In many developed countries groups of producers are able to voluntarily collect funds from members, or receive mandated *check offs*, which, in part, can (or must) be used for research (Galushko and Gray, 2014; Alston and Gray, 2013). Given the low cost of genomic-based breeding programs, they may be ideal outlets for these research funds. Governments would have to be willing to assume the costs of expanded public breeding programs similar to the way they did in the pre-transgenic era – basically to correct the market failure which would result in underinvestment in the technology.

Of course, returning crop breeding and other genetic research to an industry with a near-competitive structure will require a regulatory regime for approvals of new varieties and trade in the products of those new varieties that is not as costly and risky for those wishing to commercialize and engage in their international trade as has been the case for GMOs in a number of jurisdictions (Viju et al., 2012; Kerr, 2016a). If genomics-based technological advances were to be regulated as if they were transgenic technologies, the potential of the innovation – and its potential to contribute to meeting food security challenges – would largely be lost. Small-scale breeding programs, whether public or private, and small-scale seed firms would not be able to afford the costs and delays of an onerous regulatory regime. If intellectual property protection does not apply to genomic-based technological advances then the large multinational agribusiness firms, which have been, in some cases, able to bear the regulatory costs related to GMOs, will not be participating in the regulatory process.

Given that genomic-based technological advances in agriculture should not be subject to the same four objections that were raised in the case of transgenic-based advances – risks to human health, risk to the environment, ethical concerns and concentrated control of a central element of the food system – there should be less pressure on policy makers to create onerous regulatory systems. It is likely that politicians will still be lobbied by those suspicious of technology and the distributional effects of the changes it brings and, possibly, some vested interests. Genomics-based technological advances need to be viewed by both civil society and policy makers from the broader perspective of the need to increase agricultural productivity in aid of enhancing global food security.

As it becomes increasingly clear that the regulatory approach taken to transgenic-based technological advances by regulators and trade policy makers in a number of jurisdictions, and the EU in particular, has significantly reduced the impact which that technology could make to alleviating food security challenges (Smyth et al., 2016), it becomes apparent that genomic-based technological advances should be viewed through a new lens. It is the secondary effects[7] of the onerous regulatory regime and the international trade restrictions that accompany it that have reduced the incentives to invest in GMOs and significantly inhibited the ability to realize the technology's potential (Smyth et al., 2011; Kerr, 2015).

Genomic-based technological advances, if governed by a scientifically and socially sound regulatory environment and an open trade regime, should have the potential to contribute to overcoming global food security challenges in a significant way.[8] The EU, which has had one of the most onerous regulatory and trade regimes pertaining to GMOs, is currently assessing how to regulate genomics-based technologies (Araki and Ishii, 2015; Hartung and Schiemann, 2014). There is a great deal that can be learned by policy makers from the more than twenty years of controversy surrounding transgenic technology, so that the same mistakes are not repeated. Much will depend on how genomics-based technology is rolled out and communicated to civil society. In the case of transgenic technology, its defenders relied largely on providing formal scientific information, which often did not resonate with members of civil society. The narrative put forward by anti-GMO non-government organizations proved more effective – everything from using the term *frankenfoods* to WTO protesters dressed as GM foods in scary costumes. The framing of information on new technologies is likely to be very important in the case of genomics (Yang and Hobbs, 2017).

Genomics appears to have the potential to considerably improve agricultural productivity and thus contribute to meeting the upcoming food security challenges that have been identified. Doubling food production by approximately 2050 is no small task. It will require the types of technological advances that applying genomics can provide. The problems that have plagued transgenic technology, however, need to be avoided. A regulatory regime that encourages research and development using genomics and an open international trade regime are the keys to the technology's potential contribution to enhancing global food security.

## References

Alston, J.M. (2010) *The Benefits from Agricultural Research and Development, Innovation, and Productivity Growth*. Paris: Organisation for Economic Cooperation and Development.

Alston, J.M., and R.S. Gray (2013) Wheat Research Funding in Australia: The Rise of Public–Private–Producer Partnerships**.** *EuroChoices* 12: 30-35.

Araki, M., and T. Ishii (2015) Towards Social Acceptance of Plant Breeding by Genome Editing. *Trends in Plant Science* 20(3): 145-149.

Beddington, J. (2010) Food Security: Contributions from Science to a New and Greener Revolution. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 365 (1537): 61-71.

Buckland, J. (2004) *Ploughing Up the Farm*. London: Zed Books.

Cardwell, R., and W.A. Kerr (2008) Protecting Biotechnology IPRs in Developing Countries: Simple Analytics of a Levy Solution. *Journal of Agricultural Economics* 59(2): 217-236.

Clark. L.F. (2015) *The Changing Politics of Organic Food in North America*. Cheltenham: Edward Elgar.

Clark, L.F., C.D Ryan, and W.A. Kerr (2014) Direct Democracy, State Governments, and the Re-energized GMO Debate: Implications of California's Proposition 37. *AgBioForum* 16(3): 177-186.

Furtan, W.H., R.S. Gray, and J.J. Holzman (2003) The Optimal Time to License a Biotech Lemon. *Contemporary Economic Policy* 21(4): 433-444.

Gaisford, J.D., J.E. Hobbs, and W.A. Kerr (2007) Will the TRIPS Agreement Foster Appropriate Biotechnologies for Developing Countries? *Journal of Agricultural Economics* 58(2): 199-217.

Gaisford, J.D., J.E. Hobbs, W.A. Kerr, N. Perdikis, and M.D. Plunkett (2001) *The Economics of Biotechnology*. Cheltenham: Edward Elgar.

Galushko, V., and R. Gray (2014) Twenty-five Years of Private Wheat Breeding in the UK: Lessons for Other Countries**.** *Science and Public Policy* pp. 1-15, doi:10.1093/scipol/scu004.

Gray, R.S. (2017) Personal communication. May.

Hartung, F., and J. Schiemann (2014) Precise Plant Breeding Using New Genome Editing Techniques: Opportunities, Safety and Regulation in the EU. *The Plant Journal* 78: 742-752.

Hobbs, A.L., J.E. Hobbs, and W.A. Kerr (2005) The Biosafety Protocol: Multilateral Agreement on Protecting the Environment or Protectionist Club? *Journal of World Trade* 39(2): 281-300.

Hobbs. J.E. (2014) The Private Sectors: MNEs and SMEs. In *Handbook on Agriculture, Biotechnology and Development*, eds. S.J. Smyth, P.W.B. Phillips, and D. Castle, 56-70. Cheltenham: Edward Elgar.

Hobbs, J.E., and W.A. Kerr (2005) Will Consumers Lose or Gain from the Environmental Impacts of Transgenic Crops? In *Environmental Costs and Benefits of Transgenic Crops,* ed. J.H.H. Wesseler, 249-262. Dordrecht: Springer.

Hobbs, J.E., and W.A. Kerr (2006) Consumer Information, Labelling and International Trade in Agri-food Products. *Food Policy* 31: 78-89.

Hobbs, J.E., W.A. Kerr, and K.K. Klein (1990) Friend or Foe? – Farmer Perceptions of Biotechnology. *Canadian Journal of Agricultural Economics* 38(4): 1005-1014.

Hobbs, J.E., W.A. Kerr, and S.J. Smyth (2014) How Low Can You Go? The Consequences of Zero Tolerance. *AgBioForum* 16(3): 207-221.

Isaac, G.E. (2007) Sanitary and Phyosanitary Issues. In *Handbook on International Trade Policy,* eds. W.A. Kerr and J.D. Gaisford, 383–393. Cheltenham: Edward Elgar.

Isaac, G.E., M. Phillipson, and W. A. Kerr (2002) *International Regulation of Trade in the Products of Biotechnology*. Estey Centre Research Papers No. 2. Saskatoon: Estey Centre for Law and Economics in International Trade, http://law.usask.ca/documents/research/estey-journal/Isaac-Phillipson-Kerr_BiotechnologyRegulation_FullReport.pdf.

Isaac, G.E., and W.A. Kerr (2007) Whose Vision of the Future? The Entrenched International Conflict Over Genetic Modification. *The Geneva Post Quarterly* 2(1): 87-107.

Kerr, W.A. (2001) The World Trade Organization and the Environment. In *Globalization and Agricultural Trade Policy*, eds. H.J. Michelman, J. Rude, J. Stabler, and G. Storey, 53-65. Boulder: Lynne Rienner.

Kerr, W.A. (2015) Governance of International Trade in Genetically Modified Organisms: Is Future Global Food Security at Risk? *Journal of International Law and Trade Policy* 16(2): 60-77, http://law.usask.ca/documents/research/estey-journal/Kerr16-2lay.pdf.

Kerr, W.A. **(**2016a) Worlds Apart on GMOs – Can Trade Agreements Bridge the GAP? NABC Report 27, Proceedings of the 27th North American Agricultural Biotechnology Council Conference, Pennsylvania State University, June 2-3, 2015, 133-145. Ithaca: North American Agricultural Biotechnology Council.

Kerr, W.A. (2016b) Low Level Presence under the WTO. In *The Coexistence of Genetically Modified, Organic and Conventional Foods*, eds. N. Kalaitzandonakes, P.W.B. Phillips, J. Wesseler, and S.J. Smyth, 311-319. New York: Springer.

Kerr, W.A., and G.E. Isaac (2005) The International Treatment of Biological Material as Intellectual Property. *Journal of International Biotechnology Law* 2(3): 105-111.

Kerr, W.A., J.E. Hobbs, and R. Yampoin (1999) Intellectual Property Protection, Biotechnology and Developing Countries: Will the TRIPS Be Effective? *AgBioForum* 2(3&4): 203-211.

Kerr, W.A., and R. Yampoin (2000) Adoption of Biotechnology in Thailand and the Threat of Intellectual Property Piracy. *Canadian Journal of Agricultural Economics* 48(4): 597-606.

Klein, K.K., W.A. Kerr, and J. E. Hobbs (1998) The Impact of Biotechnology on Agricultural Markets. *Canadian Journal of Agricultural Economics* 46(4): 441-453.

Malthus, T.R. (1798) *An Essay on the Principle of Population*. London: J. Johnson.

Marks, L.A., W.A. Kerr, and K.K. Klein (1992) An Overview of the Expected Impacts of Biotechnological Research on Potato Production: Considerations for Regulators and Policy Makers. *Journal of the Agricultural Society* 71: 153-174.

Marks, L.A., W.A. Kerr, and K.K. Klein (1995) Planning for the Impacts of Agrobiotechnologies: A Guide for Public Administrators. *The International Journal of Public Sector Management* 8(1): 35-47.

Paarlberg, R. (2014) African Non-adopters. In *Handbook on Agriculture, Biotechnology and Development*, eds. S.J. Smyth, P.W.B. Phillips, and D. Castle, 166-175. Cheltenham: Edward Elgar.

Pavleska, M. (2017) *Three Essays in International Trade: SPS Agreement Violations and Concerns*. Unpublished PhD Dissertation, Department of Agricultural and Resource Economics, Saskatoon: University of Saskatchewan.

Perdikis, N. (2000) A Conflict of Legitimate Concerns or Pandering to Vested Interests? – Conflicting Attitudes Toward the Regulation of Trade in Genetically Modified Goods – The EU and the US. *Estey Centre Journal of International Law and Trade Policy* 1(1): 51-65, https://ageconsearch.tind.io/search?ln=en&p=perdikis&f=&sf=&so=&rg=&sc=.

Perdikis, N., S.L. Boyd, and W.A. Kerr (2004) Multinationals, Biotechnology, Intellectual Property and Developing Countries – Should Developing Countries Seek to Be Exploited? In *European Culture in a Changing World: Between Nationalism and Globalism*, ed. D. Meyer-Dinkgrafe, 1-10. London: Cambridge Scholars Press.

Phillips, P.W.B., and W.A. Kerr (2002) Frustrating Competition through Regulatory Uncertainty – International Trade in the Products of Biotechnology. *World Competition Law and Economics Review* 25(1): 81-99.

Phillipson, M., and S.J. Smyth (2016) The Legal and International Trade Implications of Regulatory Lags in GM Crop Approvals. *The Estey Journal of International Law and Trade Policy* 16(2): 76-90, http://law.usask.ca/documents/research/estey-journal/phillipson-smyth17-2lay.pdf.

Ryan, C.D., and A. McHughen (2014) Tomatoes, Potatoes and Flax: Exploring the Cost of Lost Innovations. In *Handbook on Agriculture, Biotechnology and Development*, eds. S.J. Smyth, P.W.B. Phillips, and D. Castle, 841-852. Cheltenham: Edward Elgar.

Smyth, S.J., J. Falck-Zepeda, and K. Ludlow (2016) The Costs of Regulatory Delays for Genetically Modified Crops. *The Estey Journal of International Law and Trade Policy*, 16(2): 173-175, http://law.usask.ca/documents/research/estey-journal/smyth-falck-zepeda-ludlow17-2lay.pdf.

Smyth, S.J., P.W.B. Phillips, and W.A. Kerr (2015a) Food Security and the Evaluation of Risk. *Global Food Security* 4: 16-23.

Smyth, S.J., P.W.B. Phillips, and W.A. Kerr (2016) EU Failing FAO Challenge to Improve Food Security. *Trends in Biotechnology* 34(7): 521-523.

Smyth, S.J., W.A. Kerr, and P.W.B. Phillips (2011) Recent Trends in the Scientific Basis of Sanitary and Phytosanitary Trade Rules and Their Potential Impact on Investment. *Journal of World Investment and Trade* 12(1): 5-26.

Smyth, S.J., W.A. Kerr, and P.W.B. Phillips (2013) Accelerating the Adoption of Genetically Modified Crops in Africa Through a Trade Liability Regime. *Plant Biotechnology Journa*l 11: 527-534.

Smyth, S.J., W.A. Kerr, and P.W.B. Phillips (2015b) Global Economic, Environmental and Health Benefits from GM Crop Adoption. *Global Food Security* 7: 24-29.

Smyth, S.J., W.A. Kerr, and P.W.B Phillips (2015c) The Unintended Consequences of Technological Change: Winners and Losers from GM Technologies and the Policy Response in the Organic Food Market. *Sustainability* 7: 7667-7683.

Smyth, S.J., W.A. Kerr, and P.W.B. Phillips (2017) *Biotechnology Regulation and Trade*. Cham: Springer.

Van den Belt, H. (2003) Debating the Precautionary Principle: “Guilty Until Proven Innocent” or “Innocent Until Proven Guilty”? *Plant Physiology* 132 (July): 1122-1126.

Viju, C., M.T. Yeung, and W.A. Kerr (2012) The Trade Implications of the Post-Moratorium European Union Approval System for Genetically Modified Organisms. *Journal of World Trade* 46(5): 1207-1238.

Viju, C., M.T. Yeung, and W.A. Kerr (2014) Zero Tolerance for GM Flax and the Rules of Trade. *World Economy* 37(1): 137-150.

*Western Producer* (2015) CRISPR: Cutting Edge Tech for Plant Breeders. November 20.

Wilson, W.W. (2014) Wheat: Status, Outlook and Implications. In *Handbook on Agriculture, Biotechnology and Development*, eds. S.J. Smyth, P.W.B. Phillips, and D. Castle, 752-769. Cheltenham: Edward Elgar .

Yang, Y., and J.E. Hobbs (2017) Communicate Food Biotechnology to Consumers Using Narratives. Presented at the Canadian Agricultural Economics Society annual conference, Montreal, June 18-21.

## Endnotes

---

[1] A few early genetically modified (GM) crop varieties were licensed prior to GMOs becoming a major political issue in the EU and are grown in limited quantities (Phillips and Kerr, 2002).

[2] Although the EU does allow some imports of GM crops as animal feed (Smyth et al., 2017).

---

[3] Although nonadoption due to the fear of losing export markets is not the only reason for the lack of investment in tropical crops. Poor intellectual property protection in developing countries is also a major contributor (Cardwell and Kerr, 2008; Gaisford et al., 2007).

[4] The *Western Producer* (2015) defines CRISPR: "[an] acronym for clustered regularly interspaced short palindromic repeats, CRISPRs are segments of DNA that contain short repetitions of base sequences followed by 'spacer' DNA called 'PAM' (protospacer adjacent motif) that indicates a cell has been exposed to a virus and has adapted a defence to it. These repeating DNA patterns, along with a family of 'Cas' (CRISPR-associated) proteins and specialized RNA molecules, play a role in bacterial immune systems. The entire complex of DNA repeats is called CRISPR/Cas. Researchers discovered one specific Cas protein, called Cas9, could identify, cut and replace any gene sequence. Scientists are now using CRISPR/Cas9 technology to create gene-editing tools that can cut and even replace undesirable genes."

[5] Although sometimes the new hybrids arrived at through conventional breeding produced crops that did not subsequently germinate.

[6] Limited property rights were, however, conferred through systems of plant breeders' rights.

[7] The primary effect is the direct trade loss from import restrictions (Gaisford et al., 2001).

[8] Transgenic technology, including those aspects of genomic-based technology that can be applied to transgenic research, will likely remain encumbered by the current regulatory regime. If that is the case, it will still have a place in the research strategies of the large transnational agribusiness firms. If non transgenic genomics technology enjoys a less onerous regulatory regime, transgenic technology will be disadvantaged and the multinational agribusiness firms will find it difficult to compete. The result will likely be reduced investment in transgenic technologies.