1. Introduction

The next time you consume a french fry, potato crisp, boiled, baked, mashed or scalloped potato, gnocchi, vichysoise, perogie or pre-cooked fish, beef or poultry, stop and think about how that food got to your plate. Each of those foods has a component derived from potatoes. On an average day, seven out of every eight people in developed countries such as Australia, Canada, European nations and the US consume one or more food products containing potatoes or potato ingredients and one in six consumers in developing countries eats some potato daily. Many consumers will also drink alcohol, such as vodka, produced from potatoes or eat meat from animals fed on potato pulp feed.¹

In addition to food uses, potatoes are also a major source of industrial starches. The starch extracted from potatoes through industrial wet milling, refining and drying is valuable to a variety of industries, including the paper and board industries, especially for paper/pulp surface sizing. Potato starch and its derivatives are also used for textiles, adhesives, surfactants, polymers, pharmaceuticals and cosmetics. There have also been efforts to use potato fibrous materials as bulk filters for plastics.

The humble potato would hardly seem to be an auspicious example of how to examine global transformations caused by converging technologies. To many it will seem to be a timeless and never-changing food, reserved for the table of the poor and oppressed. Economists somewhat derisively use the potato famine in Ireland in the 1800s to illustrate the Giffen paradox, where demand for potatoes rose even though potato prices jumped following the potato blight (which is just the opposite of what microeconomic theory would predict). The potato market exhibited this pattern because potatoes made up such a large portion of the diet that the higher prices radically lowered the purchasing power of most peasant farmers, causing them to reduce demand for other higher-priced sources of protein and instead to eat more potatoes. For the most part, the potato is viewed with disdain both within society and literature.

Nevertheless, the potato offers interesting insights into the effects of converging technologies. Over the past decade it has been the subject of increasing enthusiasm, investment, tinkering, change and debate. In the first instance, the genetic base for the potatoes we eat has been changing rapidly, as molecular-based breeding techniques have enabled seed developers to create new cultivars that meet the increasingly diverse needs of the table, the chip...
fryer, the processor and industry generally. This has yielded an increasing array of traditionally bred cultivars. For example, more than 300 varieties were registered for cultivation in Canada in the 1990–2005 period, an average of about 20 new varieties each year.

Much of the new research and development has focused on changing the production system for potatoes. Commercial production of potatoes is often fraught with risk. Two key problems are the Colorado potato beetle, which eats the foliage and stems of potato plants, and two types of virus that, when transmitted by aphids, cause leaves to curl and the stems to become woody. Extensive infestations of either pest can reduce yield, as a smaller leaf surface area limits the plant’s ability to produce and store nutrients, which reduces the number and size of the tubers. It is possible to control both problems with insecticides. An estimated 34 per cent of total insecticide in the potato sector is used to control the Colorado potato beetle, more than is used for any other pest. One difficulty for farmers is that the Colorado potato beetle has developed resistance to a number of the pesticides used, including an array of highly toxic and persistent arsenicals, organochlorines, carbamates, organophosphates and pyrethroids. Although aphids can be controlled by chemicals, the window of opportunity between an infestation and the concomitant spread of the virus can be as little as 24 to 48 hours, which makes it tricky to control.

In response to this problem, Monsanto Company, headquartered in St Louis, MO, sought to use new biotechnologies, including transgenic gene splicing, to develop cultivars which resist the beetle and viruses without reliance on chemicals. The company developed and introduced into Canada and the US four transgenic types of potato: two Colorado potato beetle resistant varieties (using a gene called Cry3A extracted and purified from a naturally occurring soil bacterium called *Bacillus thuringiensis*, *Bt*); a Colorado potato beetle and potato virus Y resistant variety (using a gene extracted from the virus); and a Colorado potato beetle and potato leafroll virus resistant variety (using a gene extracted from the virus). The *Bt* acts as an insecticide, selectively binding to parts of the beetle’s gut, causing paralysis and ultimately leading to death, and the two virus genes act to provide immunity to the plants so that the farmers need not worry about defending against the aphids.

A number of other research efforts are seeking ways to change the composition and function of potatoes. The processed food sector, in particular, wants potatoes that have lower carbohydrates (one variety currently available has 30 per cent lower carbs than competing varieties) and potatoes that are denser and have less water, so that when fried absorb less fat from the frying oils. Meanwhile, others have been examining whether potatoes might provide a higher-value service, acting either as a storage or production system for pharmaceutical proteins. One Canadian group has transgenically modified a potato to produce serpin proteins, which would then be purified for commer-
cial or pharmaceutical use. Others are working on making potatoes part of the vaccine system. As early as 1986, research showed that mice showed oral immunogenicity to the Norwalk virus after consumption of transgenically modified potatoes. By 2000, some human trials had shown immune responses. Potatoes are also being used to express vaccines for hepatitis B and E, and the human papillomavirus virus (HPV is linked to cervical cancer).

The Boyce Thompson Institute for Plant Research of Ithaca, New York, for example, in the late 1990s undertook to transgenically modify a potato to insert the vaccine for Hepatitis B, so that people might simply be able to eat a potato or a processed potato product to get the vaccine dose. Others have looked at using potatoes as a cheap, efficient, safe storage vector for pharmaceutical proteins in developing countries, where the risk of failure in the cold storage of vaccines is higher.

WHO’S IN CONTROL?

Many of us, when confronted by the list of things others want to do to the potato, are likely to ask ‘who is in control?’ Who develops, produces, processes and handles these products and who is responsible for owning, controlling, managing and assessing their contents, weight, safety, nutrition and economic, social and environmental impacts?

The simple approach is either to look to the last one who visibly handled the product – for many of us that would be a retail food store such as Carrefour, a processor such as McCain or a fast-food outlet like McDonald’s – or to the nearest government with an agency that appears to be responsible for agriculture or food safety.

The reality is that finding out who is in charge or responsible for any given product anywhere in the world is a challenge. Looking for who is in charge, or to put it another way who governs the product, is difficult because there is a complex and dense layer of actors and agencies that govern the final structure and function of almost any product available in the world today. Though potatoes represent a relatively simple example, they can be used to illustrate the point. Economists such as Herbert Simon or Paul Seabright suggest the solution to finding out ‘who’s in charge’ might be to follow the transactions. Simon has posited that if transactions emitted light or heat, a special sensor from space would show a widely different array of arrangements than we see through our traditional geopolitical lens. Seabright went further in his recent book entitled Company of Strangers, describing who was in charge of coordinating the availability of a blue cotton shirt he purchased. He used the shirt to illustrate the marvel of impersonal, uncoordinated optimizing individuals operating within markets and how they delivered a shirt on time and in the
right place to satisfy his wants. Both, however, miss the point. Each of their investigations looks at transactions, and not at the underlying norms, conventions, arrangements, laws, communities and systems that enable those transactions to occur. In the absence of some institutional arrangements, individuals cannot or will not efficiently trade, and the marvel of the market will fail.

This book investigates the names, faces, institutions and actors behind the markets and looks for an analytical and causal explanation for why at times it can be a public entity that takes responsibility, at other times the market suffices and, increasingly, purpose-built (or quite often serendipitously available) self-organized groups will emerge.

With established markets, such as for the well-known french fry, there seldom are any major concerns or questions about who is in charge. We either don’t think about who’s in charge, or, if we do, we marvel, like Seabright, that in spite of an absence of any apparent overseer, we generally get exactly what we want, when we want it.

The difficulty in sorting out control, and the costs of not having any single actor obviously tasked with responsibility, inevitably rises when new technologies are proposed, especially markedly different technologies. Despite the verbal deluge of buzz words used to describe the advent of new technology and the attendant consequences of change – radical, disruptive, transformative, major, revolutionary – the underlying premise is that a new product, process, market or organization creates new opportunities that offer both benefits and costs. Truly new ideas are most likely also to pose the greatest uncertainty – we not only don’t know how bad (or good) something might be, but also we are not even sure what the problems or opportunities arising from it might be.

In the face of uncertainty, we look to known authorities to take control and responsibility. Finding out who is likely to take control and what they are likely to do is challenging. To illustrate the point, it is worthwhile exploring the pressures on the lowly potato.

The conventional potato, without any transgenic enhancement, is governed by an array of actors that spans the globe. Finding who is really in control is a bit like peeling back an onion. Individual actors seldom control much. Most just have a specific function or aspect of the product that they control and then rely upon others to govern other aspects, either through formal arrangements or through tacit understandings (often not even mutually acknowledged).

Let’s start at the table and peel back the layers of control. The potatoes you purchased can have come into your house whole (and you will have prepared them to your taste, using a variety of ingredients and methods). Many of those potatoes, even if they aren’t bagged, are branded varieties that are aggressively marketed to differentiate them from common table varieties. These branding programs are grounded on domestic law and are either the property of indi-
individual producers or collective groups (such as the Idaho Potato Commission). If so, in most parts of the world you would have purchased them from a vendor, either a store or a street marketer. Alternatively, you might have purchased a frozen, ready to reheat packet of french fries, which are marketed as a branded product. Apart from any firm specific procedures and practices of the retailer (some of which are set collectively within the industry, such as by the Retail Council of Canada, the Grocery Manufacturers’ of America or the British Frozen Food Federation), food handlers are regulated by local, provincial, state and national laws about food safety and marketing. Many of those rules are often coordinated internationally and audited by third-party assessors. The grocers are also linked closely to the wholesalers, who have a similar set of rules and procedures to which they conform. Given that many potato products are shipped long distances and frequently across regional or national borders (for example, McCain has a large share of the German french fry market but does not have a processing operation in Germany), a wide range of rules may apply. National import and export rules and a wide array of commodity-specific and general trade agreements (such as the North American Free Trade Agreement, the European Union Common Agricultural Policy and the World Trade Organization Agreement) have effect. A series of international product, sectoral and institutional standards – such as supply chain hazard analysis and critical control programs (HACCP), sectoral International Standards Organization (ISO) standards and *Codex Alimentarius* standards – may come into effect. Moving one step further back, processors balance an array of formal government regulations related to health, safety, the environment, worker safety and industrial strategy with their corporate strategies (related to brand value and market share) and any attendant arrangements required either by their buyers (such as McDonald’s or Frito Lay) or their suppliers (legally mandated potato marketing boards and other private marketing bodies).

This brings us to the farmer, who often sees his or her lot as being squeezed by the constraints of their suppliers and the demands of their markets. Each, in turn, is increasingly proscribing the on-farm production of potatoes, specifying the bundles of inputs that must be purchased and used together (including seeds, chemicals and finance) and often establishes precise production targets for volumes and qualities, including both biochemical attributes and production and processing methods.

Moving further back in the supply chain, we come to the input providers, who market their goods or services directly or through wholesalers and sometimes are vertically connected with downstream processors and retailers. They also face an array of laws, industry rules, corporate imperatives and sectoral undertakings.

The investigation gets especially interesting when we examine the seed sector.
As noted, there has been significant interest in altering the performance of potatoes. The companies, universities, research institutes, governments, foundations and collectives who fund and undertake the basic and applied research on potatoes have an array of formal and informal rules they are constrained by and, depending on the technology and sector, have formed new institutional arrangements to manage the research enterprise. For well established products, such as the industry standard Russet Burbank variety, the underpinning knowledge and data are codified and documented in the academic journals, extension services manuals and regulatory systems.

When a new product emerges from a research effort, then, depending on the nature of the new or changed attributes, some or all of the foregoing control systems need to evaluate and decide on whether or how to adapt and adopt the technology. This process is far from linear. Given that many new traits will not fit within the competence, jurisdiction or interest of many of those currently controlling the supply chain, new institutions may be needed. Furthermore, it is likely that some changes may interest and engage a whole new set of actors and participants, frequently ones who are disenfranchised from the current control system.

Let’s consider for a moment the introduction of transgenic potatoes in the late 1990s. In the mid-1990s Monsanto Corporation accessed basic and applied science from the academic community and mobilized a team of in-house and contract researchers to adapt its proprietary *Agrobacterium tumefaciens* transformation system (using a kanamycin-resistance gene linked to a constitutive promoter) to develop a range of insect and viral resistant potato varieties. Before they could even consider entering the market, they had to undertake a three-year regulatory review, beginning with confined field trials simultaneously in Canada and the US (all of the varieties were derived from male sterile Russet Burbank potatoes, which facilitated approval from the national regulators). In Canada, the Canadian Food Inspection Agency (CFIA) and Health Canada and in the US the Food and Drug Administration (FDA), the Environmental Protection Agency (EPA) and the Department of Agriculture Animal and Plant Health Inspection Service (APHIS) evaluated the traits for human safety, safety as an animal feed and environmental impacts, using an array of established, new and negotiated procedures drawn from academia, the regulatory system, Monsanto, commercial labs and international conventions (over time the scientific process of evaluation has been formalized and codified through a variety of international agreements and conventions). As part of the approvals, both countries required Monsanto to implement integrated pest management plans (involving refugia) to ensure that the target insects did not develop resistance to the new traits.

Once the varieties were approved, Monsanto trademarked the new cultivars as NewLeaf® products and established NatureMark Potatoes to market the
products. Farmers initially seemed excited by the new varieties, as they worked to lower their use of insecticides and chemicals and thereby improve their profitability. In the spring of 1999 farmers and Monsanto were enthusiastic and optimistic about the future of this new technology and were looking forward to a cascading array of new production possibilities.

The wheels fell off the product in the fall of 1999. A number of seemingly disconnected events combined to raise a firestorm of concern in key markets for potatoes and ultimately led to the withdrawal of the product. Two events in particular mobilized a diverse group of people and institutions to work against the product. First, Dr John Losey’s work at Cornell University on the effects of Bt corn pollen on Monarch butterfly larvae, published in Nature, generated significant media hype.8 The second challenge was the controversial research on the food safety properties of Bt potatoes conducted by Dr Arpad Pusztai at the Rowett Institute in Scotland.9 Pusztai conducted a series of tests on rats using GM potatoes and concluded that the consumption of these potatoes impaired the immune system of the rats. After he announced his findings on national TV in Britain, the public debate about this new technology ballooned. Others have examined the details of this story; suffice it to say that by 2000, retailers, processors and fast-food outlets were increasingly concerned about the technology.10 Regardless of the assertions by Monsanto, the industry, the food processing industry and most scientific bodies that these products were safe, one by one different parts of the industry withdrew the product. The first to refuse the technology were British retailers, who indicated they would not sell the products. This was followed shortly afterward by Frito Lay announcing it would not use GM potato varieties and then, almost simultaneously, McDonald’s and McCain announced they would no longer buy or sell products with GM potatoes. Ultimately, Monsanto withdrew the potatoes from Maine and Prince Edward Island, offering technical help and support to producers to identify and remove GM seed potatoes from their operations.

In this case, the convergence of new technologies in the context of the global potato market was socially unsuccessful. The reason is buried deep in the governing structures that underlie the potato system.

STRUCTURE OF THE BOOK

In the rest of the book I examine the deep governing structures of transformative technology and innovation in an effort to identify which actors can be expected to act when and under what conditions and to what effect. Ultimately, it is not a question of finding a single entity that has control. Rather it is a matter of finding how a complex system of institutions and actors operates and how they can be made to enhance economic and social welfare. The book is...
not really about potatoes, but instead will examine an array of examples where converging technologies have created transformations and governing challenges. All products, whether as simple as timber produced for a building or an egg for our omelet, or as sophisticated as a replacement transmission for our automobiles or the Apple iPod, involve complex control and governing systems.

Part II of the book grounds the debate and analysis, providing assessments of the concepts of transformative technology (Chapter 2), innovation (Chapter 3) and related governing challenges (Chapter 4).

In Part III I examine the various tools commonly used to examine governing systems, including overarching paradigms for governing transformative innovation (Chapter 5) and the models and taxonomies used to investigate governing via the state (Chapter 6), the market (Chapter 7) and civil authorities (Chapter 8).

In Part IV I apply the paradigms, tools and methodologies to current transformative changes to investigate the challenges of governing in practice: first, the systems and authorities that define knowledge (Chapter 9); second, the structures that govern discovery, invention and ingenuity (Chapter 10); third, the public, private and collective processes that engage in gestating new ideas (Chapter 11); and, finally, the distributed governing networks underlying the production and marketing of new products (Chapter 12).

Finally, in Part V, I offer some observations on the implications of using deep governing systems and an assessment of the strengths and weaknesses of our tools of analysis.

NOTES
1. IENICA (n.d.).
3. Mason et al. (1996); Tacket et al. (1998), (2000); Biemelt et al. (2003); Thanavala et al. (2005); Maloney et al. (2005).