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Technoscience in Agriculture: Reflections on the Contributions of the MSU School of Sociology of Food and Agriculture

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TECHNOSCIENCE IN AGRICULTURE: REFLECTIONS ON THE CONTRIBUTIONS OF THE MSU SCHOOL OF SOCIOLOGY OF FOOD AND AGRICULTURE

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ABSTRACT

This paper argues that one of the most important contributions of the MSU School of Agrifood Governance and Technoscience (MSU-SAGT) was its focus on previously less explored and analyzed roles of technoscience in agriculture. The notion of technoscience was derived from the broader field of Science and Technology Studies, especially from Actor Network Theory. Studies conducted under Lawrence Busch's direction conceptualized this notion to indicate networks/collectives of human and nonhuman actors implicated in production, distribution and consumption of food. While these studies analyzed the role of technoscience in transforming agriculture, they also examined ethical issues (e.g., social justice and democracy) that arise from the simultaneous restructuring of social relations and practices that redistribute power and profit through various commodity chains. To highlight the contributions of MSU-SAGT to the study of technoscience in agriculture, this paper will discuss the theoretical underpinnings of this line of scholarship by comparing how the notions of networks, actors, and symmetry are used in Commodity Systems Analyses and Actor Network Theory. In our discussion, we will draw empirical examples from our work on rapeseed conducted in the 1990s. We emphasize that the application of the technoscience paradigm with innovative methodological approaches developed at MSU enabled us to problematize and theorize scientific practices in agriculture as 'politics by other means'. This explicitly raised issues of social justice and democracy as implicated in agrifood practices. This paper will conclude by emphasizing that the MSU-SAGT has stressed the importance of those temporal and spatial dimensions of technoscience politics that simultaneously transform global and local dynamics of agrifood production.

Canola oil has become a ubiquitous item in our restaurants and kitchens. Bottles and spray cans of canola oil can be found in virtually every grocery store around the world. Since the early 1980s, the oil's popularity among consumers increased significantly when its excellent dietary qualities became better known. Its high smoke point makes canola oil excellent for frying. Canola oil is also low in cholesterol and saturated fat and high in mono-unsaturated fat making it the "healthiest" of all commonly used cooking oils. However, very few canola oil consumers ever care to find out what "canola" is, what it looks like, or how it became one of the most popular oilseed plants.

In the early 1990s, to many of our colleagues, including rural and agrifood sociologists, it sounded odd, if not absurd, to use such a mundane object for a sociological study. A team of sociologists at Michigan State University (MSU) spent several years, funded by the National Science Foundation (NSF), the MSU Agricultural Experiment Station, and the Canadian Embassy, to trace the history of the plant called rapeseed (*Brassica napus, Brassica campestris*) in the New World, especially focusing on processes that transformed the rapeseed plant into canola and made this crop into an economically viable source of food and feed in North America and, increasingly, throughout the world. Over the years, under these projects, led by Dr. Lawrence Busch, five graduate students (Gunter, Juska, Tachikawa, Tanaka, and Wu) and one undergraduate (Mentele) participated in collecting and analyzing data on research, extension, production, distribution, consumption, standards, regulations, and policy on the plant to systematically examine the rapeseed commodity system that consists of multiple chains or networks across the globe. Between 1992 and 1995, the authors of this paper read countless technical articles, usually written by plant scientists or oil chemists, about erucic acid ($C_{22}H_{42}O_2$) and glucosinolates as potential "toxins" for humans and about a fungal disease called blackleg caused by *Leptosphaeria maculans.* We also read varietal registrations of nearly all the rapeseed and canola varieties planted in Canada to learn about their parentage and agronomic characteristics. Tanaka went on to complete her dissertation about rapeseed research in China; Juska, Ransom, and Middendorf later participated in a case study of soybean under one of Busch's projects. Moreover, these earlier works by the MSU School of Agrifood Governance and Technoscience (MSU-SAGT) on oilseed crops laid the groundwork for later research on grades, standards, and third-party certification.

Nearly twenty years later, few agrifood sociologists question the importance of systematically analyzing biophysical characteristics and sociocultural biographies of a given crop or livestock to understand transformations in that cropping or livestock system. Numerous commodity systems analyses (CSA) published since the late 1980s, including our work on the rapeseed commodity systems, have emphasized that "a social reality can be [easily] delineated as a discrete commodity system" (Friedland 1984:223) in which a network of human actors is linked together by a given commodity. CSA researchers argued that a careful examination of biophysical and sociocultural characteristics of the commodity is necessary to understand how it binds human and nonhuman actors together. Within CSA scholarship, our work on oilseed commodity systems is distinctive in our focus on the importance of *technoscience* in creating, transforming, and maintaining a given

commodity, linkages between actors surrounding it, and therefore a network of actors. In particular, our work is one of the earliest attempts within agrifood sociology to emphasize the importance of technoscience in shaping institutional mechanisms of agrifood governance, such as grades and standards, labels, certifications, and health claims. Moreover, this was one of the early research programs to introduce Actor Network Theory (ANT) from social studies of science and technology (Callon 1986; Latour 1987) and apply it to CSA in agriculture (Busch 1984).

This paper reflects on the contributions of the MSU School of Agrifood Governance and Technoscience (MSU-SAGT). We argue that one of the most important contributions was its focus on previously less explored and analyzed roles of technoscience in agriculture. To highlight contributions of MSU-SAGT in the study of technoscience in agriculture, this paper will discuss the theoretical underpinnings of this line of scholarship by comparing the use of the concepts: *networks*, *actors*, and *symmetry*, in CSA and ANT. In our discussion, we will draw empirical examples from our work on rapeseed conducted in the 1990s. It is important to note that the MSU-SAGT application of the technoscience paradigm proceeded with the development of innovative methodological approaches for the study of actor-networks. For example, we developed and relied extensively on use of content and/or discourse analysis to examine worldwide bibliographic references on rapeseed/canola. By the end of the oilseeds project we could operate with a coded bibliographic data base containing more than 15,000 entries enabling us to trace the globalization of rapeseed research. Also important, heuristically, was the use of sociograms in network analysis, such as a graphic depiction of relationships among networks, commodities and knowledge or relationships among plant varieties, breeders, and institutions (Juska and Busch 1994; Tanaka, Juska, and Busch 1999). A combination of focus on technoscience with the above-mentioned methodological innovations enabled us to problematize and theorize scientific practices in agriculture as "politics by other means," thus explicitly raising issues of social justice and democracy involved in agrifood practices. By "politics by other means," we emphasized the critical role of technoscience, not only in producing agricultural commodities, but also in simultaneously producing and reproducing social structure, including redistribution of wealth, power and status among actors involved in a commodity subsector. By doing so, we tried to raise questions of democracy, public accountability and social justice in designing and implementing institutional changes associated with technoscientific change and innovation. In fact, we used the term *technoscience* to highlight the interdependence of technologies

and scientific knowledge as two constituting elements of these social processes. This paper will conclude by emphasizing that the MSU-SAGT has stressed the importance of both temporal and spatial dimensions of technoscience politics that simultaneously transform global and local dynamics of agrifood production.

OILSEED SOCIOLOGY IN THE 1990S: TECHNOSCIENCE IN AGRICULTURE, AGRICULTURE IN TECHNOSCIENCE

A series of publications came out of the NSF projects on oilseed commodities that examined the interaction between the production of commodities and the production of knowledge in the increasingly globalizing agrifood economy. The work aimed to fill a gap in the existing literature at the time that analyzed the relationships between agricultural production and agricultural research, which often focuses on either the macro or micro levels of analysis, paying little attention to the macro and micro interface.

Many studies of agrifood sociology had emphasized the key role of agricultural research in transforming agrifood systems across the globe (e.g., Busch et al. 1991; Goodman and Redclift 1991; Goodman, Sorj, and Wilkinson 1987; Kloppenburg 1988). Until our work, there was a strong tendency to treat research as relatively independent from the production that enables globalization. Rarely did these studies consider how increasingly globalized agricultural production is changing the processes or practices of knowledge production in agricultural research.

On the other hand, we were equally frustrated with the science, technology and society (STS) literature available at the time. This literature treated, and still does, technoscience as an agent that *enables* the development of new products, technologies, techniques, knowledge, skills, and the organizational and geographical arrangements of economic activities. Yet, much of the STS research at the time failed to move beyond laboratories and field stations. The work on "technoscience in action," which had an impact on our work (e.g., Bijker, Hughes, and Pinch 1990; Cozzens and Gieryn 1990; Knorr-Cetina 1981; Pickering 1992), rarely examined what happens to technical artifacts beyond the scientific realm or how technoscientific and production activities interact. The literature on the globalization of technoscience (e.g., Schott 1993; Worthington 1993) paid little attention to characteristics of specific technoscientific products to examine the evolution of technoscience as a global institution.

Just as the term *technoscience* emphasizes the interaction of science and technology – or the ideality and materiality of knowledge – we have come to recognize and emphasize in our work that it is at the intersection of knowledge and

commodity production where knowledge is transformed into commodities, and vice versa, where new knowledge is generated during commodity production. In short, agricultural research simultaneously affects and is affected by the globalization of agriculture. Our analysis of oilseed commodity systems strived to illustrate how the enabling as well as excluding, subordinating and marginalizing capacities of technoscience are constituted. While working on this task, we incorporated many theoretical and methodological premises of Commodity Systems Analysis (CSA) and Actor Network Theory (ANT). In the following section, we will discuss those theoretical underpinnings by reviewing some key work that informed our approach.

Networks

In the 1980s, the explicit conceptualization of commodity systems became a useful tool for sociological studies of agricultural commodities. It became known as commodity system analysis (CSA) or commodity chain (or subsector) analysis. Some notable examples of CSA studies in the 1980s and 1990s include analyses of the U.S. lettuce commodity system (Friedland, Barton, and Thomas 1981), the tomato and wheat systems (Busch et al. 1991), the global tuna system (Bonanno and Constance 1996), the canola/rapeseed systems, the Australian poultry system (Dixon 1999), and the U.S. tobacco system (Wright 1999). To examine a network of actors surrounding a given commodity, Friedland (1984) delineated five foci of research in CSA: (a) production practices, (b) grower organization(s), (c) labor, (d) science production and application, and (e) marketing and distribution networks. More recently, Friedland (2001) has suggested that new dimensions such as grades and standards (e.g., Busch 2000), consumption (e.g., Dixon 1999a,1999b; Lockie 2001), and culture (e.g., Wright 2002) be included in CSA methodology. Although there are differences in their approaches, extant CSA studies share a central methodological characteristic: they follow a given commodity from production to consumption and examine how it and its meanings are transformed from one actor to another "within and by a network of relations" (Law 1994:18). Moreover, this approach emphasizes the organizational linkages that emerge as a commodity is exchanged among human actors within the network for further contention, negotiation and transformation. In this light, technoscience, government regulations, market rules, and patents are seen as strategies by which individuals and organizations seek to transform a given commodity. Thus, CSA was designed to specifically link the macro and micro dimensions of social transformation processes that have been long analyzed within sociology as discrete units such as

household, locality, nation-state, and global political or market system (Gereffi, Korzeniewicz, and Korzeniewicz 1994:2).

Consider the multiple institutional sites and redefinitions of rapeseed involved in transforming this crop into "canola." The rapeseed plant was introduced in North America mostly for industrial purposes – for production of hard-to-get marine lubricants during the Second World War. With the end of the war, the rapeseed market collapsed, to be revived only when Cold War tensions increased. Because of a common maritime border with the USSR, Canada's military establishment became interested in ensuring national self-sufficiency in fats and oils and began to promote the idea of transforming industrial rapeseed into a domestic source of edible fats. Thus, a redefinition of rapeseed from strategic industrial raw material into national food security issue occurred. However, laboratory experiments showed that rapeseed fed to rats significantly increased their adrenal cholesterol suggesting that rapeseed oil could be unsafe for human consumption. This led to the next redefinition of rapeseed, this time into a nutritional and pharmacological problem. Solutions to potential rapeseed toxicity were sought with launching a rapeseed breeding initiative under sponsorship by the National Research Council and Agriculture Canada. However, breeding efforts were hampered by the lack of instruments that could measure rapeseed oil components in minute quantities. Thus, the necessity of rapeseed's redefinition shifted again, this time from the realm of plant genetics and physiology toward organic chemistry. Only when appropriate tools used in organic chemistry were modified to be applicable in plant breeding, were rapeseed cultivars producing seeds without toxic substances developed.

Commodity subsector analysis also demonstrated that agrifood networks often emerge and extend far beyond the boundaries of nation-states on the one hand, and affects and is affected by political and cultural strategies of nation-states and other actors in directing economic activities both domestically and internationally. Therefore, CSA is a useful tool to investigate how economic and political activities, as well as our culture, have become increasingly globalized. For example, our studies have shown that development by Canadian plant breeders of canola cultivars in the late 1970s simultaneously led to (a) a significant increase in production of rapeseed oil for the world's markets; (b) growing competition among major crop producing countries; and (c) acceleration and restructuring of rapeseed research worldwide. Thus, Canada (the major rapeseed producer and exporter) and Japan (the major consumer of Canadian rapeseed) adopted research programs corresponding to their roles in the global rapeseed market. For example, Canadian

scientists specialized in research on pre-harvest, while Japanese scientists focused on post-harvest cycle production. Simultaneously, European Union countries (i.e., France, UK and Germany) began to synchronize their research efforts in preparation for head-to-head competition with Canadian and other rapeseed producers worldwide; US research efforts became focused on production of specialized rapeseed products for niches, especially for nonedible purposes; China attempted to transform its rapeseed research to enhance its domestic production for purposes of earning hard currency. Finally, India launched a research program to assure that country's self-sufficiency in rapeseed oil.

Furthermore, by the late 1990s when rapeseed networks became increasingly globalized, we traced how the nation-state as the defining space for economic activities including research had begun weakening while several large transnational actors such as input suppliers, especially seed companies, and processors, were gaining the capacity to shape the fate of rapeseed as an economic and research object (Tanaka et al. 1999). For example, many canola varieties of the 1990s and onward were developed by multinational seed companies, rather than national agricultural research institutes or university laboratories funded by the government, which contracted scientists from different countries.

Similar to CSA and commodity chain analysis, ANT, delineated by Bruno Latour (1987, 1993, 1999), John Law (1992, 1994, 1999), and Michele Callon (1986, 1999; Callon and Latour 1992), assumes that an objectifiable reality can be delineated as networks of social relations between actors. In studies of laboratories by Latour (1987, 1988) and Latour and Woolgar (1979), these researchers followed scientists, lab technicians, and research assistants to observe closely the processes (or movements) through which a scientific claim was developed, and verified, or, on the contrary, contested and refuted. In short, ANT focuses on the processes of technoscience and practices of scientists, technicians and engineers through which a network of social relations emerges, changes, extends, and collapses – or how the enabling (or constricting and precluding) capacity of technoscience is constituted.

Besides treating a network of actors as a unit of analysis, CSA and ANT share two additional key assumptions about the network under study. First, networks change over time and differ across space. For example, the analysis of historical changes is essential to understanding the current social arrangements within a given commodity system. Moreover, regional variations in a particular activity (e.g., crop cultivation, crushing, research), the organizational arrangement of a network, and the meaning of a product/commodity often hold important clues to answer why some actors from particular geographical locations have been

(un)successful in rapidly extending their network links beyond their locale. Actors in the network surrounding a commodity or a technoscientific problem often constantly change as well. For example, in the early post-WWII period when rapeseed was produced primarily through manipulation of the environment (or dependent on soil weather conditions, pests, weeds, seeds, harvesting, fertilizers, pesticides, and crop rotation) farmers had most control in the rapeseed commodity network. By the 1970s, when rapeseed utilization as a raw material began to increase, the rapeseed processing industry became dominant within the commodity's networks. Finally, by the 1990s, control over rapeseed networks moved to scientific settings where development and application of agricultural biotechnologies became decisive in restructuring the oilseed subsector (Juska and Busch 1994).

Whether agriculture or technoscience, activities that take place in the network are always situated and embodied in a particular place and time. This is why both CSA and ANT studies often scrutinize major historical points of change in the network by asking: How did the change come about? Who and what actors actively participated in the process of change at a particular point while others were excluded from it? What were the factors that enabled certain actors to shape and transform the network, while others were marginalized and excluded from this process? One of the starkest examples of redistribution of wealth within the rapeseed commodity system occurred when the Canadian rapeseed network was extended across the Pacific Ocean to include Japan, a traditional producer as well as consumer of rapeseed oil. In the early 1970s, Japan, under intense pressure from the US opened its internal market for North American soybeans and other oilseeds, but continued to impose tariffs on imports of processed oil. Such policies were very beneficial to large Japanese crushers, but drove Japanese rapeseed farmers and small crushers out of business. On the other side of the Pacific Ocean, the biggest benefactors of changes in trade policies were Canadian rapeseed farmers as they gained direct access to a previously protected rapeseed market. However, Canadian crushers were devastated when almost overnight they were left with only half of the domestically produced seed to process. Significant overcapacity of Canadian crushers quickly created huge financial losses and led to takeover of the industry by foreign multinationals (Busch and Juska 1997).

Such a restructuring of global rapeseed markets indicates that power relations are constitutive of the network and that not all actors in a given network are equal. The historical analysis over approximately 50 years, using both qualitative and quantitative data, of rapeseed research, production and trade of rapeseed and its

byproducts revealed that diverse human and institutional actors from various economic interests, political motivations, and sociocultural needs were enrolled into the processes of transforming rapeseed from a minor oilseed plant from the Old World to a major global oilseed crop, called canola, which can be used for animal feed and edible oil products. As emphasized in Busch et al. (1994), "the story of canola is the intersection of many stories," in each of which actors such as farmers, grain elevators, the Canadian Government, the Canadian Department of National Defense, the Winnipeg Commodity Exchange, the FDA, the biotechnology research and development firm Calgene, plant breeders, chemists, rats, and Canadian extension agents played important roles in shaping the power dynamic of the network. This and the historical narrative about blackleg epidemic (Juska, Busch, and Tanaka 1997) showed that the locus of power in the network is always in flux because a major change in the rapeseed/canola commodity system could be induced by a series of most unexpected events (e.g., the introduction of gas-liquid chromatography for fatty acid analysis) or an impact of occurrences far removed from the immediate canola production and processing setting (e.g., pressure put by the U.S. on the Japanese government to open its domestic market for imports of oils and fats).

A crucial shortcoming of CSA is that such a network of social relations surrounding a commodity only exists in the market. Indeed, a commodity system (or chain) is a system of labor processes in which a commodity is produced, processed, distributed, and consumed (e.g., Friedland 1984; Heffernan 1984). Thus, commodity system studies rarely look at the process by which a given commodity market emerges. Therefore, very often such activities as R&D, policy making, and civic activism are viewed as exogenous to the economic and social processes, and are neglected. However, as Juska and Busch (1997) demonstrated, there are multiple networks in constant change surrounding a given commodity such as rapeseed. For example, the networks of rapeseed production and rapeseed research intersect with each other at various points, or nodes, because many actors simultaneously belong to several networks. These inputs/outputs, processing, delivery and distribution networks operate relatively independently because each consists of different actors with its implicit as well as explicit sets of rules, interests, and strategies to maintain, strengthen and extend the linkages with actors inside and outside the network.

The second problem is closely related to the first. Many commodity chain studies in the world systems literature (e.g., Korzeniewicz 1994) often give a static picture of commodity chains. Therefore, they do not offer any explanations why some actors (usually nation-states and TNCs) have become and remain part of the

core and others remain peripheral in the global division of labor. Consequently, they often describe, but often do not explain the transformation of commodity chains over time and variations of these chains across space. This weakness largely comes from the assumption that macro-structural conditions preexist before the global commodity chains have formed. Therefore, these studies fail to recognize that actors create, maintain and change particular structural conditions to advance their role in a given commodity chain.

Being aware of these CSA shortcomings, we tried to extend our analyses beyond the immediate domain of the market, to also include other domains intersecting with agrifood production. For example, rapeseed market globalization was shaped by several factors including, but not limited to, the US and USSR rivalry in the Cold War, the elimination of erucic acid and glucosinolates by Canadian scientists, changes in quality standards for rapeseed and its products, the removal of trade barriers for oilseeds, and changes in nutritional consciousness among consumers (Busch et al. 1994; Busch and Tanaka 1996; Juska and Busch 1994).

Moreover, we emphasized that the processes of network building are continuously negotiated and contested. We tried to demonstrate this with analyses of agrifood networks in such as countries as China, Russia, and Lithuania where sociological categories such as structure, nation-state, public, and private are increasingly in flux. Thus, they allow commodity systems researchers to bring the question of what is entailed in the transition from a socialist to more market-oriented economy to the center of the analysis.

Finally, by conceptualizing a commodity system or chain as something that consists of multiple networks, researchers can recognize that "everything is uncertain and reversible" (Law 1999:4) and that stability in holding patterns of links becomes a source of power. This realization has significant implications to social scientists as activists by directing us to look for and scrutinize the nodes of entry into networks for both, research and political action, thus allowing us to raise issues of social justice and participatory democracy. Like many ANT studies, our analysis began with an investigation of controversies – points of uncertainty and destabilization within networks – such as those over erucic acid and glucosinolates as toxicants, blackleg as a nationwide epidemic in Canada, and changes in grades and standards of rapeseed and its byproducts. We then asked: How was each controversy settled? How were the networks surrounding that controversy reordered? What new set of norms, rules, and values were established to govern the networks to maintain stability? Who were included in, and excluded from, the processes? By answering these questions, our work on the rapeseed commodity

system contributed to an understanding of governance as the processes and mechanisms of ordering, simplification, and stabilization of the networks, and therefore redistribution of power among network actors/actants.

Actors

Despite an ever growing list of odd terminology, such as *relational materialism*, *semiotics of materiality*, *translation*, *enrollment*, *immutable mobile*, and *blackboxing*, to name a few, the methodological approach of ANT is very simple and shared by CSA – follow the actors. By following a given actor (i.e., a commodity in CSA, a technoscientific product or scientists and engineers in ANT), the analysis focuses on transformation processes of social groups, things, interactions between human and nonhuman actors, and interorganizational relationships. Often, each actor is assumed to bring into the network a distinctive set of interests, motivations, goals, perspectives, values and ethical commitments negotiated with those of other actors. Therefore, a given product (i.e., a technoscientific product in ANT, a commodity in CSA) represents an outcome of such negotiations.

However, the two approaches differ significantly in their conceptual treatment of *humans* and *nonhumans*. ANT emphasizes the *heterogeneous materiality* of networks (Law 1994), and thereby explicitly treats humans and nonhumans as actors/actants in a network. In other words, things such as instruments (or "inscription devices") and lab animals actively participate in settling technoscientific controversies and ordering the social world. Interpretation of nonhumans as actors/actants has fueled much debate in the literature of science studies (e.g., Callon and Latour 1992; Collins and Yearley 1992a, 1992b), commodity studies (e.g., Friedland 2001; Goodman 1999; Lockie and Kitto 2000) and beyond.

In our rapeseed studies we explicitly adopted and tried to consistently apply the heterogenous materiality of the networks approach. Thus, we treated canola (rapeseed varieties with low erucic acid and glucosinolate contents) as an actor/actant that was actively involved in shaping linkages among farmers, processors and researchers in Canada as well as internationally (Busch and Juska 1997; Juska et al. 1997; Tanaka 1998). Similarly, in our work on rapeseed standards we demonstrated how both rapeseed plants together with rapeseed breeders, canola farmers, processors, and others are involved in reciprocal definition of each other. For example, plants could define (based on the characteristics of productivity, resistance to diseases and shattering, quality of oil produced, etc.) how good or how successful is the farmer and *vice versa*. In such interpretations, standards are treated as a relational category determined by negotiations among actors over, for example,

what constitutes good rapeseed as an agricultural crop, a raw material for edible and industrial oil products, and a plant for experimentation. No matter how high yielding Farmer Li's rapeseed (which is an important element of "good rapeseed" for him), if his harvest does not meet specific qualitative characteristics that his marketer wants, it will be rejected. Then, what Farmer Li has considered as "good rapeseed" is not good after all. Instead, he must integrate his marketer's notion of "good rapeseed" (e.g., cleanliness, freedom from damage, low erucic acid) into his own value and practice to produce the very rapeseed that his marketer wants. The conceptualization of networks of heterogeneous materials surrounding a given commodity allows us to interpret it as a network of relationships that is spread across a wider geographical space, involves more individual and corporate actors, and often penetrates deeply into our own daily activities. In fact, every one of us is part of agrifood commodity systems as consumers, citizens and/or activists. We know that our "relationships" as consumers, citizens and activists with banana growers in Ecuador, wine exporters in France, soft-drink companies in Japan, and biotechnology companies in the U.S. in these commodity systems are mediated through television, magazines, computers, internet, telephones, airplanes, ships, refrigerators, packing material, food labels, etc.

For example, rapeseed chains across the globe are embedded in the spatial and temporal specificity in which the actors are located. Thus, Chinese and Canadian researchers study rapeseed quite differently and maintain their own unique set of linkages with other actors in their own local rapeseed chain. Simultaneously, these researchers are linked together in the global networks of rapeseed research and production (Tanaka 1997). They may engage in research collaboration, or merely read and cite each other's work without any physical encounters. Germplasm from their respective institutes may be exchanged as their breeding materials. Yet by following rapeseed in China and Canada, local specificity of rapeseed and the commodity chain surrounding it in these two countries as well as the linkages between the Chinese and Canadian rapeseed chains in the global networks of rapeseed research and production can be empirically demonstrated. As discussed below, the methodological approach of following actors helps to trace linkages extending from one (historical and relational) space to another – from production to consumption, from local to global, from micro to macro, and from nature to society.

Symmetry

In ANT, the motivations or intentions of acts in these processes are never assumed to be reflected in the outcomes of these acts. Rather, ANT focuses on acts as outcomes and effects. This focus on acts, rather than the relationship between the motivations and effects of these acts, makes the issue whether nonhumans have agency unimportant. What is important about nonhumans such as lab plants and animals, tools, equipment, texts is that they do make humans act and construct a worldview embedded in a particular relational space.

Thus, in our rapeseed studies we asked not only how do farmers plant, care and harvest rapeseed? How do marketers collect, store, package, and deliver rapeseed? How do processors process rapeseed into various products? How do retailers market different brands of various rapeseed products through diverse retail channels? Or how do consumers consume these rapeseed products? Of equal importance for us was to investigate what nonhuman actors such as farm tools, mechanical harvesters, freezer cargos, and brand names afford farmers, marketers, processors, retailers, and consumers to act. We found that answers to these questions vary significantly across time and space. Without the analysis of nonhumans as actors, researchers cannot properly elucidate what, how and why human actors in a given commodity system do what they do. This methodological focus on acts/practices enabled us to recognize uncertainty, changeability and fluidity of the commodity networks because acts/practices change over time and across space.

Take as an example, the rapeseed commodity system. Its configuration at any particular point in time is shaped not only by strategic actions or intentional maneuvering of many corporate or individual actors, but is also affected by contingent events and unexpected alliances between actors. New alliances are constantly formed, replacing weak ones; the network is continuously expanded or contracted. While studying rapeseed technocience we tried to be especially conscious to recognize that there are power relations among actors in networks, and that all actors are not equal. Power disparities among human actors, for example, between transnational corporations (TNCs) and local contractors, are already built into the structure of a market economy.

Simultaneously we emphasized that technoscience also represents a very important although often overlooked aspect of power relationships that allow some actors to successfully bring in or enroll more human and nonhuman actors into a given network to modify a commodity and thereby enhance their status, power and profits within the network. For example, seed companies often have more power

and control over the global rapeseed chain than farmers. This is because these companies have more resources and expertise in changing the biological features of rapeseed, planting practices and the relationships among seed producers, sellers and buyers. While pursuing their interests, seed companies often invest in research projects, lobby for policy changes and make financial deals with competitors and subsidiaries. They also seek out new actors outside the commodity chain, and more important, turn these new actors and/or actants into their allies and resources, for example, by using rapeseed germplasm from China, applying new research findings in molecular biology and enrolling new customers in traditionally non-rapeseed producing countries. However, all those resources do not guarantee that seed companies will become dominant in the global rapeseed system. Instead, their power as an actor in the rapeseed system is only realized when they succeed in changing the rapeseed plant and modifying the behavior of other actors.

As we found in our studies, production of new knowledge and introduction of new technologies often destabilizes the chain as any number of actors attempt to take advantage of advances in technoscience. Thus, the attempt of one actor to change the chain may be blocked by other actors to preserve their position. Additionally, actors may ally with each other to support their position against that of a competitor in the network.

Consider what Tanaka found in her fieldwork in China in 1996. Despite a higher procurement price, most Chinese farmers did not grow canola varieties developed by Chinese researchers and recommended by local extension agents. To farmers, who had been consuming rapeseed oil over generations, the elimination of erucic acid (which is allegedly toxic to humans) did not make sense. Also, the elimination of glucosinolates (which is toxic to animals) was not particularly useful since buying feed to raise one or two pigs in a household would not be cost effective at all. More important, the new varieties yielded less and were harder to manage ("too bushy!") than the traditionally popular varieties. This low adoption rate of canola varieties by farmers consequently led both the national and provincial governments to exclude the levels of erucic acid and glucosinolates from the quality specification in the standards of rapeseed and its oil products.

Compared with their counterpart in China, the rapeseed network in Canada has been successful, not only because rapeseed as a commodity travels further across the globe, but the commodity also moves between human actors faster, once harvested, and continuously delivered to consumers in varied forms with consistent quality even during the plant's off-season. However, this conquest over temporal and spatial barriers in the globalized rapeseed system does not necessarily homogenize

practices of rapeseed production, distribution and consumption as well as moral and ethical values attached to rapeseed across the globe. In Japan, for example, despite the demise of rapeseed farming, people continue to love the sight of blossoming rapeseed on river banks, eat the flowers as a side dish, paint pictures of rapeseed fields, use the plant for biology lessons, and name their children after rapeseed (similar to Daphne, Daisy, Rose in English). Meanwhile, most American canola oil consumers do not even know what canola plant looks like.

CONCLUSION: GLOBAL POLITICS OF TECHNOSCIENCE

We do not claim that the MSU-SAGT was the only or first group to study agrifood technoscience as a topic or incorporate ANT into agrifood studies (e.g., Murdoch 1994; 1997). As the usefulness of ANT in the sociology of food and agriculture became more widely recognized, it also stimulated several debates on drawbacks and limitation of this approach (Buttel 2001; Friedland 2001; Goodman 2003). These can be grouped into two categories. The first one centered on defining the ontological status of "actants," i.e., on defining the nature of and intentionality of actions by nonhumans (as compared to actions/intentionality of humans) within actor networks. The second set of issues focused on ANT's heuristic power and epistemological limitations. An outlining of these extensive debates goes far beyond the scope of this paper and is available elsewhere (see Friedland 2001; Lockie 2001). Here we would like to indicate that some actor networks theoretical limitations were already outlined in our studies. For example, we argued for epistemological "modesty" of actor network theory because it constituted an empirically driven approach. Therefore, ANT analysis is much better suited for micro and meso as opposed to macro-structualist studies. These epistemological ANT limitations were also pointed out by Friedland (2001:91-92) who argued that, instead of representing a full encompassing theory, ANT could be better characterized as theoretically informed methodology. He also noted the better suitability of ANT for analyzing change in a subsector as opposed to a study of a network that is stable, as well as the weakness of ANT in explaining failed attempts to create or extend networks.

In retrospect it can be argued that MSU-SAGT scholarship provided important contributions to and stimulated recent studies on scientific practices in agriculture as well as examination of institutional aspects of the increasingly globalized agrifood system, including more recent work on grades and standards (e.g., Bain 2010; Bain, Deaton, and Busch 2005; Bingen and Busch 2006; Tanaka and Busch 2003), regulations (e.g., Juska et al. 2000, 2009; Tanaka 2005), certifications (e.g.,

Bain and Hatanaka 2010; Hatanaka, Bain, and Busch 2005; Hatanaka and Busch 2008), agrifood governance (e.g., Bain et al. 2005; Busch 2010; Busch and Bain 2004), and research funding (e.g., Rudy et al. 2007; Tanaka and Bhavsar 2008). In the dissertation and post-dissertation work, each of us has applied various theoretical and methodological approaches to open the black box of how the "rules of the game" or "invisible hands" are: negotiated among actors across time and space, transform global and local dynamics of agrifood production, and become subsumed into our mundane, everyday life world. To accomplish that, country-based case studies of commodity systems have been carried out in various countries spread across six continents of the world. Through our collective scholarship, we argue that without an examination of global networks of technoscience it is difficult to observe the processes in which such reconfigurations of the game are made possible by spatially and temporary situated (often contingent and unrelated) actions and the impact of these reconfigurations across space and time.

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