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How farmers matter in shaping agricultural technologies: social and structural characteristics of wheat growers and wheat varieties

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Abstract Science and technology studies (STS) research challenges the concept of technological determinism by investigating how the end users of a technology influence that technology's trajectory. STS critiques of determinism are needed in studies of agricultural technology. However, we contend that focusing on the agency of end users may mask the role of political-economic factors which influence technology developments and applications. This paper seeks to mesh STS insights with political-economic perspectives by accounting for relationships between availability of diverse technologies, variations in political-economic structures, and farmer interests and characteristics. We present the results of an analysis on the recent development of three wheat varieties: (a) a wheat variety that was modified genetically to tolerate the herbicide glyphosate, (b) wheat varieties with characteristics selected to serve specific markets, (c) and emerging research and development of perennial wheat varieties. Using data obtained through a survey of wheat growers in Washington State, we analyzed whether farmer interest in these three clusters of wheat varieties was associated with distinct individual characteristics and attitudes and whether those characteristics and attitudes are consistent with political economic structures. Although our analysis did not allow us to assess the degree of direct influence that farmers have on the technological development trajectory for these types of wheat, we were able to document variation in technological alternatives and farmer characteristics related to different political-economic trends.

Keywords Farming · Genetically modified · Niche marketing · Participatory · Technological determinism

Abbreviations

GM	Genetically modified
SESRC	Social and Economic Sciences Research Center
WAWG	Washington Association of Wheat Growers
WSU	Washington State University

Introduction

Science and technology studies (STS) scholars challenge the concept of technological determinism by investigating how the end users of a technology influence that technology's trajectory. Technological determinism refers to the idea that technological influences on society are unidirectional and guided by inherent characteristics of the technologies, not by social or cultural factors (Bauchspies et al. 2006). Smith and Marx (1994) divide technological determinists into "hard" and "soft" categories. Hard determinists portray science and technology as having agency to change history, usually cast as an element that inevitably leads toward either progress or calamity. Soft determinists claim that a technology has a decisive

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influence in history. However, soft determinists assign the ability to influence not to the technology itself, but to a complex mix of social, economic, political and cultural factors that embed and imprint a direction upon the technology (Smith and Marx 1994). STS scholars contend that the problem with both the soft and hard versions of technological determinism is that they tend to overlook the role that end users play in the process of technological development and dissemination (Pinch and Bijker 1987; Kline 2005; Oudshoorn and Pinch 2005).

Technological determinism has been prominent in explanations of agricultural change and development. Proponents of agricultural industrialization in the United States, and of the Green Revolution, have often linked technological change with social progress (Kloppenburg 2004; Buttel 2005). For example, Green Revolution proponent Simmonds (1979: 38) states that "…plant breeding, in broad social terms, does indeed generate substantial benefits and is remarkably free of unfavorable side effects (the economists' externalities)." Simmonds goes so far as to say that the products of plant breeding are beneficial regardless of political, economic, and social contexts.

Research conducted from a critical perspective has challenged some of the hard deterministic assumptions associated with analyses of agricultural technologies, but has perpetuated a soft determinism by stopping short of exploring how users of a technology can shape a technology's trajectory. Theories of agricultural science and technology would benefit from Oudshoorn and Pinch's (2005) insights on how the people that ultimately use technologies influence the development and applications of those technologies. However, as one considers the influence of farmers as users of agricultural technologies, it is important not to reify the agency of farmers. As Karl Marx (1978, p. 595) famously asserted, people "make their own history, but they do not make it just as they please …" Social structural trends, after all, place limits on the types of agricultural technologies available and the capacities of farmers to utilize them; consequently, limiting the agency of farmers.

In this paper we seek to synthesize STS and political-economic theories. Specifically, we develop statistical models to illuminate how structural factors and technology end users influence technological developments. Our critique of the prominence of a soft technological determinism in the agricultural literature lead us to propose that theories of agricultural technological development need to consider how farmer characteristics, in addition to variations in political-economic structures, can be utilized to explain technological trajectories in agriculture. Using data obtained through a survey of wheat growers in Washington State, we assess our assumptions and determine if farmer interests in different types of wheat might be grouped according to social characteristics, and whether those social characteristics are consistent with broad, divergent agricultural structural trends. We divide those structural trends into Fordism, post-Fordism, and anti-Fordism. If the data suggest that farmers can be divided into groups that favor one or more of the wheat varieties over the others, and the data also show that particular characteristics are consistent with political-economic structural trends, then we will have evidence that the viability of alternative technologies may hinge on characteristics of end users as well as on political-economic structures. Such results would contribute to a more nuanced sociological view of the interaction among farmer characteristics and interests, political-economic trends, and research processes of technological development and dissemination.

The study provides substantive implications in addition to theoretical ones. Lobao and Meyer (2001, pp. 103–104) argue that current trends in agriculture may lead to the end "of farming as a household livelihood strategy," especially for small to medium-sized farms. At the same time, they contend that the expansion of alternative, ecologically friendly production systems indicates that the "fate of the farm population is not yet sealed" (Lobao and Meyer 2001, p. 119). The persistence of agriculture as a household livelihood strategy may depend to a significant extent upon the ability and willingness of university plant breeders and other scientists who develop new agricultural technologies to respond to the needs of farmers and other citizens who seek to reduce their reliance on inputs produced by large businesses; and assert some degree of expanded autonomy over their own small businesses. If researchers want to develop technologies for more than just a segment of the farming population, they need to become aware of how their technologies fit within broader political-economic trends and how they are perceived and utilized by distinct farmer groups.

Agricultural technology and end users

Social scientists in the 1970s and 1980s began to challenge the notion that agricultural technologies lead inevitably towards progress; and that political, economic, and social contexts do not matter in the shaping of technological development. With the concept of the agricultural technological treadmill, Cochrane (1993) describes the negative social consequences of new agricultural technologies. Similarly, Heffernan (1972), Rodefeld (1978), and Danbom (1979) recognize a link between new agricultural technologies and increased farm size (see also Buttel et al. 1990). They acknowledge the role of end users to the extent that they highlight cases in which farmers resisted (albeit unsuccessfully) adoption of technological changes.

However, an implicit soft technological determinism persists in these approaches, since these authors stop short of addressing how variations in the social characteristics of the farmers might explain variations in technological trajectories. The end user of the technology is portrayed as being influenced by the technology, not vice versa.

Sociologists studying university crop researchers have also perpetuated a soft technological determinism in their studies by focusing on the political-economic contexts that shape plant breeding research agendas. For example, Kloppenburg (2004) argues that, during the middle of the twentieth century, corn yields could have been increased without hybridization. However, the U.S. Department of Agriculture promoted hybridization because it provided a biological patent that would attract the private sector's involvement in plant breeding (Kloppenburg 2004, p. 35).[1] Also in a study of the effects of corn hybridization on farmers, Fitzgerald (1993) argues that corn hybridization led to a de-skilling of the farm production process.[2] The theorized effects of the technology in these studies are unidirectional. There are exceptions to the soft determinism approach to studying agricultural technology development. Buttel (2001) points to evidence that the only time farmers offered significant support to the land-grant university system was when hybrid corn and other breakthroughs were being disseminated to farmers. He speculates that this is because university research was addressing a tangible issue for farmers. The implication is that farmers may find a technology useful and welcome it, even if it might lead to a loss of autonomy. The fact that a majority of farmers might welcome a technology that could ultimately de-skill those farmers and facilitate a decline in farm numbers does not undermine Kloppenburg's or Fitzgerald's perspectives. But it does indicate a need for more complexity in theorizing about how agricultural technologies are developed and the degree to which they may be accepted or resisted by potential end users. What is often overlooked, according to Schurman (2003, p. 19), is that "the meaning, consequences, and transformative potential of any particular technology depend upon how that technology is deployed, by whom and for what purposes and upon the meanings it is given by those who use it." A more complex theory of agricultural technology should explore variation in farmer interest in different technologies, as well as whether farmers might be categorized according to different political-economic structures. Such an approach could help address the tendency within theoretical perspectives that are based upon soft and hard versions of technological determinism to overlook the role that end users play in the process of technological development and dissemination.

Among sociologists who study agricultural technology, Friedland and Barton (1975), [see also Friedland et al. (1981)] come closest to developing such a nuanced theory when they describe how plant breeders and agricultural engineers in California developed tomato and lettuce production-related technologies to replace farm laborers during an era when farm laborers became better organized. However, vestiges of soft determinism persist in this theory; that is, by focusing on the interaction between political-economy, technology, and labor. They theorize that large farmers participated in the development of the technology, to the extent that it is acknowledged that large farmers wanted a technological substitute for labor. However, farm labor is treated as a monolithic category in relation to political-economic structures. Their analysis says more about structural inequalities of the political and economic system than about technology and the technology's end users.

Incorporating Schurman's (2003) observation into Friedland and Barton's (1975) theoretical insights, we contend that it is not just how particular technologies are employed, but also what available technologies might compete with the deployed technology, that shape the social processes connected to technological development. For example, Buttel (2001) is likely correct to claim that farmers favored hybrid corn because it contributed to increased yields. However, farmers might have preferred high-yielding open-pollinated varieties had such varieties been available, because those farmers would have been able to save and replant seeds from open-pollinated varieties. In other words, if farmers during this era had a choice between hybrid corn and open-pollinated corn varieties that produced similar yields, farmers might have had more of an influence on the trajectory of plant breeding in corn. However, without such an option, and without sufficient data on which farmers were more or less likely to prefer hybrid corn to a comparable non-hybrid corn, it is impossible to adequately gauge relationships between the development of hybrid corn and the social characteristics and interests of farmers.

Due to recent developments in wheat varietal development, however, we are able to explore the current relationships between variation in agricultural technology trajectories (i.e., different wheat types) and the social characteristics and interests of farmers. University and private-sector wheat breeders are in the midst of developing three types of wheat varieties with unique

[1] Because it is not practical to successfully save seed from hybrid corn for the following year's planting, farmers who commit to using hybrid corn would need to purchase seed each year.

[2] De-skilling refers to a situation whereby workers' skills are replaced with a technology. It involves the reduction of the knowledge and practical activities of workers in a labor process. For example, when artisans or craftspeople become assembly line workers they can be said to be de-skilled. In the case of farming, hybrid corn de-skilled because it replaced seed-saving and varietal selection knowledge and skills of the farmer.

characteristics: herbicide-tolerant wheat, specialty wheat, and perennial wheat. Using data obtained through a survey of wheat growers in Washington State, we sought to determine if farmer interests in those varieties differed. Furthermore, we sought to establish how farmer interests in those different types of wheat might be justifiably grouped according to social characteristics—and whether those social characteristics are consistent with broad, divergent agricultural structural trends. The aim overall was to how farmer interests in technological options might influence the further development of those technologies.

Data

In the fall of 2005, we conducted a survey of Washington State wheat growers in collaboration with the Social and Economic Sciences Research Center (SESRC) at Washington State University (WSU). The sampling frame for the study was the Washington Association of Wheat Growers (WAWG) membership list. According to the WSU archives, WAWG is a corporate member of the National Association of Wheat Growers and was incorporated in January 1955 to: (1) improve strains and by-products, (2) develop new markets, (3) conserve natural resources, and (4) promote the interests of wheat growers.[3] Our sample limits our ability to generalize to all farmers in the United States. The WAWG list of farmers is representative, however, of commercial farmers in the Pacific Northwest who grow wheat as their primary crop. Small-scale and certified organic growers may be underrepresented in WAWG because organic growers may have preferences for grower associations that better serve their information and networking needs. Nonetheless, because scientists associated with the WSU wheat breeding program work closely with commercial wheat farmers in Eastern Washington, the wheat growing region, the WAWG list was deemed an appropriate sampling frame.

The survey was developed in collaboration with SESRC experts. Questions were developed to seek out farmer demographic information and perspectives on a range of issues. We utilized Likert scales of 1–3 or 1–5 to invite farmers to indicate their level of interest in such things as particular kinds of wheat, their level of satisfaction with aspects of the WSU wheat breeding programs, and their level of involvement with university extension programs. The survey questions were edited and formatted to form an eight-page booklet that took about 15–20 min for farmers to complete. We worked closely with six farmers who were asked to test the survey for clarity and ease of completion before we mailed to respondents. Using a current (WAWG) list with WAWG's approval, the SESRC mailed the survey to all WAWG members. Questionnaires were sent in accordance with the procedures outlined in Dillman's (2000) *Tailored Design Method*. Commercial farmers growing wheat as a primary crop were deemed eligible to participate in the survey. A cover letter and the survey were sent to each member on February 14, 2006, with a reminder postcard sent on February 2, and a final mailing to non-respondents on March 7. Receipt of completed surveys for data collection was closed on April 7th, 2006. There were a total of 1,374 names on the mailing list, of which 557 returned completed questionnaires, for a response rate of 41%. An additional 239 were returned and judged ineligible, giving a return rate of 61% and a completion rate of 52%, which is good for a survey of this type.[4]

Beforehand, a series of grower roundtables were held in Eastern Washington counties to help us to develop reliable and meaningful survey questions; and utilized afterward facilitate interpretation of the results. Farmers were recruited to participate through the recommendation of farmers in the counties who were interested in WSU research and were already collaborating with the WSU winter wheat breeding program. Roundtable discussions were held in Franklin and Whitman Counties on March 4, 2005, to help develop survey questions. After the survey was completed, roundtables were held May 31, 2006, in Spokane County; June 1, 2006, in Benton County; November 18, 2006 in Adams County; November 30, 2006, in Whitman County; and November 30, 2006 in Franklin County.

The STS literature, especially work on how users of a technology matter, tend to rely on qualitative research methods. However, we believe that it is possible to operationalize key concepts from this earlier body of work in a quantitative analysis of survey data. We recognize that we would need to use ethnographic research techniques to make claims about the meanings that farmers assign to the technologies that they incorporate into their operations. However, our goal was to determine if insights from the STS literature may be generalizable to a broader farm population than ethnographic research normally allows.

Social characteristics of wheat

Because more than one technological set (in terms of wheat varieties) is now potentially available to wheat farmers, it

[3] Language taken from http://www.wsulibs.wsu.edu/holland/masc/finders/cg370.htm (accessed 1 April 2010).

[4] Although missing cases tended to be less than 10% for each variable, the SPSS program deletion of missing cases during logistic regression reduced our sample size by as much as 200. After running tests to determine that missing cases were randomly distributed, we used the SPSS program's linear interpolation function to replace missing cases.

became possible for us to explore whether there was a relationship between agricultural structures, technological alternatives, and farmer characteristics and interests. Plant breeders are developing three types of wheat varieties, which we used as a heuristic device for categorizing farmers and their relationships with respect to agricultural structural trends. The first type of wheat included wheat varieties that are genetically modified (GM) to be herbicide tolerant.[5] The second type included specialized wheat varieties bred to have high value for food processors and consumers. The third was perennial wheat, which is designed for low-input farming and intended to increase farmer autonomy. Based on these options, we constructed three hypotheses to test whether farmer interest in particular wheat varieties corresponded to groups of farmers who had divergent interests, farm management practices, and structural political-economic positions in the agricultural system.

Hypothesis 1 Herbicide-tolerant wheat will be associated with farmers whose practices are consistent with Fordist farm management and who accept a strong role for private-sector research.

"Fordism" refers to the capitalist, political-economic regime that emerged in the Twentieth Century to manage and integrate mass production and mass consumption. The term Fordism is derived from the received view of the organization of the mass production system as pioneered by Henry Ford, but its use was extended to identify the political-economic structures that were developed for regulating a political economy dominated by mass production. Part of this conceptualization rests on the notion that economic expansion in the Twentieth Century depended in large part upon the consumption of undifferentiated products built on assembly lines by de-skilled laborers and consumers. Another part of the conceptualization recognizes that the smooth accumulation of capital necessitates an accord between workers and those who own and manage the production process. Thus, it is in the nation-state's interest to forge a pact between labor and industry to prevent a capitalist crisis of overproduction and underconsumption (Bonanno 1998; Bonanno and Constance 2001). In the Fordist context, this process included the mass production of goods consumed by those in the working class producing these goods.[6]

Applying the concept of Fordism to agriculture, Kenney et al. (1989) and Friedmann and McMichael (1989) describe the role of the state in collaborating with agribusiness to manage the efficient use of natural resources, technological development, uniformity in production, and human resources with the goal of maximizing production for mass consumption, and minimizing possibilities for conflict. Agricultural research and development at land-grant universities contributed to the creation of a Fordist regulatory system in agriculture. University research was traditionally seen as important because its institutional goals are distinct from the private sector. Industry (a private institution) tends to conduct research with the goal of generating proprietary goods. The university (a public institution) has traditionally conducted research, particularly in the agricultural sector, with the goal of producing public goods (Lacy 2000; Welsh and Glenna 2006). The Fordist state promoted research in both private and public institutions to balance proprietary and public goods, because both were considered necessary to enhance social welfare. However, the land-grant university's emphasis on public-goods research came to be seen as an impediment to capital accumulation; hence, a disincentive to private investment in agricultural research (Kloppenburg 2004).

The development of hybrid corn and, more recently, the development of GM crops, have privileged the agribusiness side of the private–public research and development collaboration (Buttel et al. 1984; Busch et al. 1991; Kloppenburg 2004). Because herbicide-tolerant wheat was developed through university-agribusiness collaborations, and because intellectual property protection enables agribusiness to enhance capital accumulation, the example epitomizes the high Fordist industrial agricultural model of promoting capitalist accumulation through mass production of commodities for mass consumption. Agribusinesses mediate the relationship between mass raw material producers (in our case, farmers) and mass consumers by selling inputs to farmers and by processing and adding value to the commodity. Research and development leading to technological innovation in the input and processing components of the agricultural system are the products of private research institutions, but often are developed through private–public research collaborations. Because the research and development is directed at the private-

[5] At least one herbicide-tolerant wheat variety was derived from mutation breeding. Therefore, it is not technically genetically engineered, but may be called genetically modified (GM). It is also important to note that there are other herbicide tolerant wheat varieties in the pipeline that have not yet been commercialized.

[6] We are not making normative judgments regarding the social and economic impacts of Fordism, post-Fordism, or anti-Fordism. For example, someone using a utilitarian argument could make a case that the "mass production for mass consumption" model of production yielded social benefits. Someone using a rights-based or virtue theory of ethics could argue that harm to farmers, who were driven out of business by the mass-production system, outweighed the benefits. We recognize strengths and weaknesses in each of these arguments. However, the goal of this paper is to determine if we can categorize farmers according to these structural trends and whether those categories can help us to understand the social and economic significance of different types of wheat.

sector goal of profit accumulation, it is assumed that farmers interested in herbicide-tolerant wheat will have a more favorable disposition towards agribusiness and private sector agricultural research and development.[7]

Hypothesis 2 Specialty wheat will be associated with farmers who engage in post-Fordist farm management, a so-called "niche marketing" strategy that is directed at diverse production, processing, and marketing strategies, and with a prominent role for public-sector research.

Post-Fordism is the term used to describe conditions emerging from contradictions in the Fordist system, including rising costs of production, declining productivity and market saturation (Bonanno and Constance 2001, p. 4). Although many dispute the causes and consequences of the phenomenon that is labeled post-Fordism (e.g., Friedland 1994; Goodman and Watts 1994), there is recognition that there has been a significant shift in the political and economic structures of many industries, including agriculture and manufacturing. Commentators use the terms "flexible accumulation" and "flexible specialization" to indicate a shift from the mass production and mass consumption system characterized by Fordism to a more heterogeneous system of quantity and quality of production under post-Fordism (Bonanno and Constance 2001), at least in some products. When applied to agriculture, Kenney et al. (1989) used a post-Fordism framework to describe the diversification of farm production, including shifts to specialty crops and markets, while Jussaume (1991) applied the ideas to describe emerging patterns of agricultural trade.

Specialized wheat varieties that are developed to be appealing to specific food processors represent one dimension of a post-Fordist system. For example, a wheat variety bred for specific starch or gluten profiles may be especially appealing to pastry chefs. Such specialized characteristics and marketing strategies are a deviation from a Fordist mass production and mass consumption model, where, conceptually at least, all wheat is the same. Furthermore, by breeding for specialty traits, plant breeders potentially offer farmers the opportunity to add value to the wheat they produce by growing varieties targeted at specific end users. Of course, such cases bring about the possibility of sub-contracts with end users, rather than the firms that provide the inputs, thus leading to a shift in relative power of actors in the commodity chain. Compared to Fordism, post-Fordism ideally provides farmers with more production and marketing options. Whether the use of such varieties can lead to more farmer autonomy in the political-economic structure is unclear.[8]

Hypothesis 3 Perennial wheat will be associated with resistance to appropriationism (anti-Fordism); and with a belief in a prominent role for public sector research.

A key dimension in the development of the Fordist system of mass production and mass consumption has been "appropriationism." Appropriationism refers to the tendency of large firms, including agribusinesses, to take over a greater share of the production and processing components of small-scale production or retail operations (Pfeffer 1992).

When agribusinesses increasingly supply farm inputs and take over commodity processing, the scope of the farm production process becomes narrower and further integrated into a commodity chain that is dominated by an actor at a single stage in the chain. As for herbicide-tolerant wheat, an important component of the appropriation process has been the role of agricultural research and development. As Kloppenburg (2004) argues, hybrid corn and GM crops bring intellectual property protections that enhance agribusiness goals of profiting from the farm production process. Agribusinesses have also enhanced their control of the broader agricultural system by purchasing multiple segments of the production and processing system, which is referred to as horizontal and vertical integration (Heffernan 2000). As an indicator of the reduced role for farmers in the production process, agribusinesses began to refer to farmers as outsourced "raw material" suppliers for agricultural commodity processing companies during the 1985 Farm Bill debates (Glenna 2003).

Pfeffer (1992) describes how the sustainable and organic agriculture movements represent a form of resistance to agribusiness efforts to co-opt farm production processes. Sustainable and organic agricultural practices tend to reduce input substitutions as well as maintain some level of farmer control over the agricultural production process. Sustainable and organic farming techniques stand as an alternative to those technological developments that were central to the development of the Fordist, industrial agricultural model. Therefore, one might infer that an interest in such alternative technologies indicates that such farmers are concerned about the loss of autonomy in the Fordist system.

[7] It is important to clarify that land-grant university research has been and remains diverse. Indeed, the point of this paper is that land-grant university crop research may be more diverse than the political-economy theories acknowledge. However, trends in research funding and institutional goals have led scholars to raise concerns about the increasing emphasis on private-goods research at land-grant universities (see Glenna et al. 2007).

[8] Bonanno and Constance (1996, 2001), also Antonio and Bonanno (1996) have characterized post-Fordism as a corporate strategy for outsourcing production with the goal of circumventing Fordist environmental and labor regulations. Thus, we use post-Fordism to refer to the emergence of production, marketing, and consumption practices that are more flexible and diverse than the mass production and mass consumption Fordist system and which may or may not be associated with changes in labor relations.

Perennial wheat represents the most significant departure from the Fordist industrial-agricultural model because the explicit goal of the perennial wheat breeding program to reduce the dependence of farmers on agribusiness for seed and other inputs. Breeders involved in the perennial wheat program are also seeking to develop participatory relationships with farmers to develop low-input and organic wheat varieties that will re-skill farmers in the labor process and enable farmers to retain a greater share of profits from the production process (Murphy et al. 2005).[9] WSU wheat breeders began developing participatory breeding pilot projects in 2003 to work with farmers in diverse farming systems and microclimates to develop new wheat varieties (Dawson and Goldberger 2008). This represents a direct challenge to at least one appropriationist aspect of Fordism because farmers are reclaiming the seed selection portion of the farm production process.

Analysis

In order to test our hypotheses, we selected several variables related to farmer perceptions of the structure of agriculture, as well as attitudinal and production-practice variables that have implications for agricultural research. Specialty Wheat, GM (in our case, herbicide-tolerant) Wheat, and Perennial Wheat serve as our dependent variables (Table 1). These dependent variables are treated as ordinal variables. Farmers were asked on the survey to indicate with a 1, 2, or 3 whether they had low, medium, or high interest in these three different types of wheat. We found a broad distribution of interest, with farmers expressing the highest interest in specialty wheat, but we also found high and medium interest expressed in GM wheat and perennial wheat.

As noted in the theory section, we selected independent variables to correspond to our goal of determining relationships with theories of Fordist, post-Fordist, and anti-appropriationist production and marketing and theories of private/public research and development (Table 2). We include a column in Table 2 to indicate whether a positive response to each variable served as an indicator of farmer support for or rejection of Fordist, post-Fordist, or anti-Fordist strategies. The variables "Interest in Niche Markets," "Rebuilding Regional Infrastructure," and "Limited Market Opportunities" are consistent with a post-Fordist trajectory that moves beyond the system integrating model of mass production and mass consumption. In addition, we conceptualized "Preventing Pest Resistance," "Genetic Diversity," and "Environmental Conservation" to capture concerns arising in response to some of the perceived environmental consequences of a Fordist mass production system. However, each item suggests a different approach to addressing the problem. "Preventing Pest Resistance" reflects an approach to field management that would enable the monocropping of the Fordist system to continue. In contrast, concerns about genetic diversity and environmental conservation convey an effort to diversify cropping systems, which runs counter to the Fordist model. Therefore, we would consider a high score on "Preventing Pest Resistance" to be an indicator of a favorable attitude towards Fordism but high scores on "Genetic Diversity" and "Environmental Conservation" to suggest post-Fordism or anti-appropriationist perspectives among farmers.

Table 1 Percentages of wheat grower interest in wheat varieties

	High	Medium	Low
Specialized wheat for specific market segments	55.07	36.71	8.22
Herbicide tolerant wheat	45.33	44.19	10.48
Perennial wheat	28.87	41.87	29.25

Following Pfeffer's (1992) discussion on the development of low-input agriculture, we conceptualized "Concerns about Technology Agreements," "Considering Organic," and "Planting Saved Seed" to indicate an attitude in opposition to appropriationism. Those individuals who are opposed to technology agreements, who save seed, and who are considering making the transition to organic agriculture are likely to be interested in deviating from the mass production system dominated by agribusiness. In the Agricultural Research and Information Dissemination category, we include "Participatory Breeding," "Attend Field Days," "Private Company Agricultural Research," and "Agribusiness Magazines." We assume that those with high scores on "Private Company Agricultural Research" would tend to think that private sector research can replace public sector research. Those who rely on "Agribusiness Magazines" to get their information would also indicate a favorable attitude towards agribusiness. Because University Field Days are sponsored by the university, a high score on the variable "Attend Field Days" would indicate a favorable attitude towards university research, although it would not preclude a favorable attitude towards agribusiness research. "Participatory Breeding" represents a vision of research that at the very least could be deemed as an alternative to appropriationism. Similar to the development of perennial wheat, a participatory approach to plant breeding is intended to

[9] Although WSU wheat breeders have authored articles on the role that perennial wheat breeding could play in participatory and organic agriculture, this is not a stated goal of the WSU wheat breeding program. Currently, the program is emphasizing reducing inputs, reducing soil erosion, and increasing farmer autonomy. This information will be important when we interpret our data analysis on farmer interest in perennial wheat.

Table 2 Descriptive statistics of independent variables

	Mean (SD)[a]	Hypothesis[b]
Agricultural structure and farming practices		
Interest in niche marketing	2.02 (.86)	PF+
Interest in rebuilding regional infrastructure to allow more local control	1.91 (8.0)	PF+/AF+
Negative challenge: limited market opportunities	2.30 (.77)	F−/PF+/AF+
Importance for farm success: preventing pest resistance	2.44 (.63)	F+
Importance for farm success: environmental conservation	1.95 (.80)	PF+/AF+
Importance for farm success: genetic diversity of wheat	2.04 (.75)	PF+/AF+
Influence of GM technology agreement on decision to grow GM wheat	1.27 (1.24)	F−/AF+
Plant saved seed	.83 (1.20)	F−/AF+
Considered transition to organic	.133 (.34)	F−/PF+/AF+
Agricultural research and information dissemination		
Interest in a participatory wheat breeding program	1.21 (.77)	F−/AF+
Private agribusiness firms can replace work done by universities	.80 (.71)	F+/AF−
Importance of information source: agribusiness magazines	1.42 (.84)	F+/AF−
Importance of information source: university research program field days	2.00 (.90)	PF+/AF+
Demographics		
Total farm receipts	5.35 (1.25)	NA
Education	2.58 (.85)	NA
Age	57.57 (12.94)	NA

[a] Variables represented by scales of 0–3; with 0 = not important or no interest; and 3 = extremely important or very interested. Total farm receipts is divided into seven categories: 1 = less than $2,500 to 7 = more $500,000 or more. Education is divided into four categories: 1 = high school or less, 2 = some college or vocational, 3 = college degree, and 4 = post-college study. Age is continuous

[b] F+ indicates that we hypothesize that this variable will have a positive, significant coefficient and thereby reflect support for Fordism. F− indicates that we hypothesize the variable will have a negative, significant coefficient and thereby reflect a rejection of Fordism. Similarly, PF+ and PF− indicate support for or rejection of Post-Fordism. And AF+ and AF− indicate support for or rejection of Anti-Fordism

counter the trend of farmers paying for seed each year and is anticipated to give farmers more control over variety development (e.g., Murphy et al. 2005).

We also requested information about total farm receipts, education level, and age to serve as control variables in our models; farm size, age, and education are variables commonly used in innovation and diffusion studies. We chose farm receipts instead of farm acreage to measure socio-economic of farm operation, because farm acreage is not a good measure of farm "size" in Eastern Washington. There is a great deal of natural variability in rainfall in the region. In parts of the region, rainfall is sufficiently low that land is limited to being farmed only every other year, thus increasing the size of farms because only half of the land is in production at any one time. Farm acreage is therefore more accurately interpreted as an indicator of geographical zone than socio-economic status of the farm operation.

Discussion

The results of our analysis indicate that we are justified in categorizing farmers according to typologies that correspond to the three types of wheat varieties. The typology also successfully incorporates social characteristics of farmers with regard to agricultural structural and research trends (Table 3). Farmers interested in specialty wheat were more likely to indicate interest in efforts to develop alternative markets, to express concerns about limited market opportunities, and to show a desire for development of wheat varieties that promote genetic diversity. They were not likely to plant saved seed or to get their farm information from agribusiness magazines. These variables remain significant when controlling for education, farm receipts, and age. Although we hypothesized that more post-Fordism variables would be significantly associated with an interest in specialty wheat than was observed in the empirical results, we believe these findings offer some support for the proposition that the development of specialty wheat varieties is consistent with interest on the part of some farmers in several elements of post-Fordism.

We found that several variables generally supported our hypothesis that GM wheat is related to variables reflective of support for Fordist agricultural production practices. Farmers interested in GM wheat were much less likely than other farmers to have considered transitioning to organic farming. This correlation, along with the significant, negative relationship with "Technology Agreement," suggests

Table 3 Ordered logistic regression on specialty wheat, GM wheat, and perennial wheat (1 = low, 2 = medium, 3 = high interest) ($N = 523$)

	GM wheat estimate (SE)	Specialty wheat estimate (SE)	Perennial wheat estimate (SE)
Agricultural structure and farming practices			
Niche marketing	.098 (.116)	.445** (.122)	−.051 (.112)
Rebuild regional infrastructure	−.045 (.125)	.511** (.132)	.239* (.121)
Limited market opportunities	.309* (.118)	.422** (.123)	−.060 (.113)
Prevent pest resistance	.317 (.168)	−.026 (.176)	.008 (.160)
Genetic diversity	.119 (.149)	.478** (.160)	.169 (.143)
Environmental conservation	.067 (.132)	.135 (.140)	.300* (.127)
Technology agreement	−.246** (.077)	−.012 (.081)	−.050 (.073)
Plant saved seed	.129 (.079)	−.185* (.083)	.086 (.076)
Considered transition to organic	−.652** (.254)	.300 (.281)	.523* (.245)
Agricultural research and information dissemination			
Participatory breeding	−.153 (.127)	.056 (.133)	−.161 (.122)
Attend field days	.144 (.104)	.207 (.109)	.219* (.100)
Private company Ag research	−.116 (.123)	.025 (.131)	−.316** (.118)
Agribusiness magazines	.225* (.113)	−.316* (.121)	−.050 (.108)
Demographics			
Total farm receipts	.006 (.079)	−.006 (.084)	−.195* (.076)
Education	.062 (.110)	−.131 (.118)	−.203 (.107)
Age	.014 (.008)	.003 (.008)	−.004 (.007)
Nagelkerke Pseudo R^2	.115	.223	.103

* $p < .05$, ** $p < .005$

that farmers interested in GM wheat are less concerned than other farmers about appropriationism. Farmers interested in GM wheat also, as predicted, rely on agribusiness magazines for production information. These variables remain significant when controlling for education, farm receipts, and age. We also found a positive, nearly significant ($p < .05$) relationship between GM wheat and "Prevent Pest Resistance."

However, our model did not perform exactly as we hypothesized. Because we hypothesized that GM wheat would be significantly associated with Fordism, we were surprised to find a significant, positive relationship between GM wheat and "Limited Market Opportunities." We had also expected that farmers interested in GM wheat would be positively associated with the opinion that the private sector can replace public sector agricultural research, which was not the case. Since some results support our hypothesis and others do not, we cannot accept or reject the hypothesis outright. Rather, we believe it is necessary to recognize that farmers interested in GM wheat hold more complex attitudes towards corporate-dominated agricultural commodity markets than we originally hypothesized, based on our review of the literature on Fordism. Therefore, we interpret our results as offering limited support for the proposition that the development of GM wheat is consistent with a Fordist model of agricultural development. At the same time, it is clear that differentiating farmers and agricultural technologies according to Fordist, post-Fordist, and anti-appropriationist categories has limits.

Similarly, we found partial support for our hypothesis regarding perennial wheat. Farmers interested in perennial wheat are more interested in "Environmental Conservation" than those not interested in perennial wheat. They are also much more likely to have "Considered Transition to Organic." They tend to disagree with the idea that private agricultural companies can replace the public sector in agricultural research and they are more likely to have attended WSU field days. These farmers also tended to report lower farm receipts than farmers not interested in perennial wheat. These findings are consistent with our hypothesis that perennial wheat is likely to be attractive to farmers who desire an alternative to a Fordist model. However, we were surprised to learn that interests in "Participatory Breeding" and "Planting Saved Seed" were not significantly associated with perennial wheat, because we conceptualized all three of these variables as representing a resistance to appropriationism.

Ironically, although the results of our statistical analysis provide only partial support for our hypothesis, they indirectly confirm our broader theoretical perspective. More to the point, the findings indicate that end users may have an interest in a technology for reasons other than what the technology's developers intended. It is also important to keep in mind that, although plant breeders have stated that

perennial wheat may enable farmers to resist appropriationism (see Murphy et al. 2005), the WSU wheat breeding program's stated goal is to promote perennial wheat to reduce soil erosion, and not increase farmer autonomy.[10] If the program were to promote farmer autonomy as an explicit feature intended to challenge to appropriationism, a follow-up study might elicit results that could more directly address our hypothesis.

Conclusion

The goal of this paper has been to supplement political-economy theories of agricultural technology with insights from STS on the influence of end-user beliefs on a technology's trajectory. It is our contention that the relatively limited amount of research on farmers as end users of agricultural technologies has privileged monolithic and deterministic portrayals of technological development and transfers over more comprehensive theoretical views of agricultural technological development. Political-economic theories of agricultural technology remain important. Research indicates that a Fordist regulatory model has been associated with the industrialization of agriculture, the gradual replacement of farm labor processes with agribusiness inputs, and a system of mass production and mass consumption. Fordism has coincided with a decline in farm numbers, an expansion of farm size, and a trend of fewer and larger farms accounting for a greater share of agricultural commodity production. It also has been connected to the rise of a few, large agribusinesses that have accumulated a greater share of commodity markets and processing capacity. Furthermore, sociological studies on agricultural research and development emphasize the power of these companies to influence university (i.e., public) plant breeding research. However, theories of agricultural technology remain incomplete until they can explain how, in addition to political-economic structures, farmer interests and characteristics influence farmer perspectives on new technologies, as well as influence changes in agricultural.

Our research indicates the existence of a diversity of farmer interests in wheat varieties and production and marketing strategies among wheat growers in Washington State, USA. Although the analysis did not coincide perfectly with our conceptualization of different technological development trajectories, we found evidence for the proposition that there is variation in support among groups of famers for broad agricultural structural trends and diverse technological developments. Furthermore, the interest in specialty wheat and its association with wheat growers' interests in expanding marketing strategies indicates that the mass production and mass consumption Fordist model may partially be giving way to a post-Fordist model; at least to the extent that specialty wheat varieties and farmer production and marketing interests indicate the continued emergence of more flexible and diverse production and marketing strategies. Overall, this corresponds with a more nuanced theoretical perspective. Specifically, Fordism, post-Foridsm, and anti-Fordism do not represent different historical periods, but rather coincide with each other. The simultaneous interest in and availability of different types of wheat varieties, each associated with different socio-economic characteristics, suggest that the future of wheat farming is not predetermined by agricultural technologies or political-economic structures. Our findings strongly suggest that the interests of the end users of agricultural technologies influence the type of research conducted on wheat varieties. Future social research may indicate that other agricultural technologies can also be categorized according to farmer interests and characteristics, as well as political-economic structures.

The findings have practical ramifications for how proponents of a more ethical and sustainable food system may design educational and extension programs to meet the needs of diverse farm groups. The social and economic impacts of agricultural technologies are not predetermined, but rather are shaped through a complex interaction of technologies and individuals within broader political-economic structures. This process has yielded an array of wheat varieties that seem to correspond to different kinds of famers. Therefore, university research extension programs, which are expected to serve a diverse farm population, should not presume that pursuing narrow research and extension objectives, such as maximizing yield for mass consumption, will serve distinct farm populations equally. A university plant breeding program that chooses to focus exclusively on the development of GM wheat, for example, would be privileging one segment of wheat farmers.

Policies and individual scientist's decisions—and the way they shape university research and extension programs—have implications for the viability of a diverse array of farmers. As noted in the introduction, Lobao and Meyer (2001) argue that current trends in agriculture may lead to the demise of small to medium-sized farms. At the same time, they contend that the expansion of alternative, ecologically-friendly production systems indicates that the "fate of the farm population is not yet sealed" (Lobao and Meyer 2001, p. 119). The persistence of agriculture as a household livelihood strategy, and the future of plant breeding as a public enterprise, may depend to a significant extent upon the ability and willingness of university plant

[10] See http://plantbreeding.wsu.edu/perennialWheat.html (accessed 1 April 2010).

breeders and other scientists to recognize that technological trajectories are not inevitable and to respond to the diverse needs of farmers and other groups of citizens who seek alternatives to mass production strategies.

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