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Science and Technology in World Agriculture: Narratives and Discourses

Pasquale Lucio Scandizzo
University of Rome "Tor Vergata"

The narratives characterizing the current debate on world agricultural research tend to be part of a discourse that rationalizes past experience and future tendencies along the lines of extreme recounts of successes and failures. Stories of agricultural development and of accomplishments of research and science in agriculture tend to be organized according to either a conservative or a radical paradigm, which are in sharp contrast with each other and are at the origin of basic disagreements and biased information. For the neutral observer, these contrasting views—to the extent that they seem to concern facts more than opinions—cause disorientation and stress in the form of the well-known phenomenon of cognitive dissonance. Among the international institutions, the World Bank appears to have taken on the responsibility of attenuating such a phenomenon by providing, through its own narratives, stylized truths and balanced interpretations.

Key words: agriculture, research, narratives, discourse, cognitive dissonance, biotechnology, global public goods.

Narratives and Discourses on World Agriculture

According to Abell (2007), "…human beings frequently claim to understand events when they manage to formulate a coherent story or narrative explaining how they believe an event was caused or, more often, how the world is causally transformed from one state to another by virtue of human agency/action." The crucial nature of narratives in interpreting reality through story telling, however, goes beyond the search of causal explanations in the absence of strong statistical evidence from recurrent events. But what exactly is a narrative? Wikipedia claims that

> a narrative or story is a construct created in a suitable format (written, spoken, poetry, prose, images, song, theater, or dance) that describes a sequence of fictional or non-fictional events. It derives from the Latin verb *narrare*, which means "to recount" and is related to the adjective *gnarus*, meaning "**knowing**" or "**skilled**." (Ultimately derived from the Proto-Indo-European root *gnō-*, "to know") The word "story" may be used as a synonym of "narrative," but can also be used to refer to the sequence of events described in a narrative. A narrative can also be told by a character within a larger narrative.

Because of their rhetorical nature, and the fact that they involve characters, plots, and color, narratives provide a more attractive cognitive framework for interpretation and search for meaning than other more descriptive or more quantitative structure of causal explanations.

On the other hand, narratives can be wildly divergent amongst one another in interpretation, meaning, and scope and cause what in psychology is known as *cognitive dissonance*. This condition may give rise to the cognitive stress of entertaining two contradictory ideas simultaneously. In fact, the theory of cognitive dissonance (Aronson, 1969) proposes that one function of narratives may also be used to reduce this dissonance by rationalizing outcomes, modifying beliefs, and justifying differences between reality and self images. According to one economic interpretation (Akerlof, 1989), information bias and endogenous preferences may be both the cause and the effect of these phenomena and of the inefficiency of related resource allocation.

The debate on world agriculture provides an interesting example of contrasting narratives along these lines, as two dominant and conflicting sets of stories confront each other. In their stark alternative recount of the facts, they seem to reproduce the dichotomy described by the structuralist literature between the self-evident, matter-of-course recount of popular origin (the "doxa") and the more neutral attempt at recapitulating the facts (the "para-doxa"). Pierre Bourdieu (1972) identified with doxa "the fundamental, deep-founded, unthought beliefs, taken as self-evident universals, that inform an agent's actions and thoughts within a particular field." Roland Barthes (1981, 1982) was instead concerned with the conflict of two types of language: that of popu-

lar culture, which he saw as violent and limited, and the neutral language, which he saw as open and noncommittal.

For the evolution of world agriculture, the moderate, or conservative narrative tells stories of achievements and hopeful developments with no villain and many heroes. This story is one of uninterrupted scientific progress, continuous increases of yields in the past years, even though, it is admitted, a notable slowdown has progressively occurred as the initial effects of the green revolutions have been gradually consumed and, at the same time, the expected increases from biotechnology have not yet materialized. For example, recounts of the green revolution, how it came about, how it has affected farmers' lives, etc., are common stories consistent with the conservative narrative theme.

A radical, or contrarian, set of narratives elaborates stories along a different theme: while the large farmers have benefited from yield increases, smallholders, whose yields have traditionally been far in excess (from 200 to 1000 times) of those of large farmers, have gained only marginal benefits; only in those cases, where the large increases in supply following the yield increases, have not resulted in a sufficiently large fall in prices with a consequent net fall of their incomes per acre. Two similarly contradicting sets of stories characterize discourses on the parallel debate on the environmental impact of science and technology on agriculture.

According to Foucault (1972, 1977, 1980, 2003), discourses define the limit of what can be acceptably said about a subject, but these limits depend on competing claims on specialized knowledge. In all cases, they are a form of communication, where the very choice of the words anticipates the thesis that is being promoted. In the case of agricultural research, one discourse is elaborated from the supporters of the present system, who are, in a sense, the primary claimers to specialized knowledge on the subject. As such, they acknowledge the insufficient amount of resources devoted to agricultural research, but claim nevertheless that past and present efforts have been very effective (average yearly rates of return above 40%) and environmentally virtuous. In this discourse, biotechnology, in spite of its apparent risks and widespread suspiciousness and hostility on the part of many, has demonstrated effectiveness and environmental neutrality, if not virtuosity.

An opposing, radical discourse appears to originate from a longer-term vision of the future, and thus, from a more subtle and sophisticated claim to specialized knowledge on the social and economic consequences of agricultural research. This discourse elaborates profoundly contrarian views. Not only science and technology have been proving to be essentially ineffective in pushing the agricultural frontier beyond the achievements of the green revolution, but biotechnology—the real culprit of the story—has proved to be a totally negative instrument, responding to profit rather than needs, irrelevant for developing economics, and threatening to the environment. This threat is multiple and grave. It is based on the inevitable suppression of biodiversity and climate change adaptation capacity consequent to the diffusion of few genetically engineered homogenous crops with superior input or output traits. It is also based on a host of dangerous resistance-building processes associated with insecticide and herbicide resistance as well as DNA/virus-connected contamination. The increasing use of biofuel adds a further, ominous threat to the undesirable features of a system based on commoditization and oligopoly. In the words of Annie Shattuck:

> We don't need agro-fuel plantations to solve our energy problems. Neither do we need GMOs to overcome food price inflation or to combat hunger. In the words of many activists, "We need to turn the industrial food system on its head." The vision for a new food system is well reflected in the growing movement for food sovereignty, "the right of all people to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems." This means dismantling the control companies like ADM, Cargill, Bunge, Monsanto, Syngenta, and DuPont exercise over our food systems—control that is held in place both by regulations—like the renewable fuel standards—that force us to consume their products, and the GM technologies that limit our options to one: theirs. We need to support movements for food sovereignty that promote policies and technologies for local rather than international markets; for keeping people on the land, rather than driving them off; and for bringing genetic diversity back into agriculture, rather than reducing it to the GMO patents held by a few corporate oligopolies. (Shattuck, 2008, pp. 7)

The contrast between the conventional and the contrarian discourse is reminiscent of the opposition between the modernist inclination to attribute scientific discoveries to unqualified social progress and the more

problematic attitude of postmodernism toward the nexus between recognizable social progress and the empowerment of the elites. But it may also reflect different power positions of the parties involved, both because, as Foucault (1977, 1980) argues, science and truth are shaped by negotiating power and because discourse operates by rules of exclusion, so that power is assigned to the privileged who can speak and are listened to.

The Ethical Problem

An ethical theme has been highlighted by a radical discourse on agricultural research as the source of progressive commoditization, whereby agricultural products all around the world are transformed into commercial goods bereft of any sacrality or social and community value. According to this line of thought, commoditization determines dangerously de-humanizing agricultural processes of production, especially when applied to livestock. Commoditization also relates to the observed alienation of smallholders as a viable social institution (the family farm), the development of monoculture, and the loss of biodiversity. It ultimately results in the creation of massively urban-biased societies, based on the unsustainable demography of the megalopolis (or the "infinite city").

Consistently with Bourdieu's argument on the force of popular opinion in considering the present state of the world as self justifying and of its consequent power for self-reproduction (Bourdieu, 1972), and with Foucault's idea on the limits of acceptable truth (Foucault, 1980), a further narrative of the contrarian type elaborates on the theme of the removal of this disturbing discourse from the collective consciousness. In the words of Paul Thompson (1998, pp.13), one of the most authoritative agricultural ethicists:

> Agricultural producers and those who support them with technology may have been seduced into thinking that so long as they increased food availability, they were exempt from the constant process of politically negotiating and renegotiating the moral bargain that is at the foundations of the modern democratic society. Our attitude is "full steam ahead," especially because we are expecting 3 billion additional people by 2050. The discoverers of new technologies, the gene cloners, the lawmakers who support farm subsidies, the plant breeders, the pesticide manufacturers, the organic farmers, and the globalization or protesters against agricultural biotechnology generally are unwilling to accept criticism for their actions, for all "know" that they have made the correct choice.

The roots of an ethical discourse for agricultural science can thus be recognized in a radical critique of the conservative and dominant discourse on agricultural progress. The radical discourse, in spite of its essentially antagonistic and paradoxical nature, is credible in both its ethically consequentialist (consequences may be dire without appropriate standards) and proceduralist dimensions (respecting the rights of existing organisms is the foundation of our own liberty). Within this discourse, the main story concerns the parable of agriculture seduced by the mission to provide plenty of nutritious food at the lowest possible costs for all, but losing sight of its secular functions of land stewardship, preservation of the environment and providing access to nature, assurance for survival, and substantial freedom. In the words again of Annie Shattuck:

> The international farmers' movement La Via Campesina sees seeds as the "heritage of mankind for the good of all humanity." The movement offers a drastically different vision of agriculture from the industrial model being pushed through the agrofuels boom, a model based on family agriculture, locally cultivated seeds, and food sovereignty. Increasingly, they are being joined by movements for community food security and neighborhood food systems throughout the industrial North. As farmers and consumers of the global North and South come together on food sovereignty—in policy and in practice—we will find ways to take back our food systems. (Shattuck, 2008, pp. 7-8)

A less appealing aspect of this radical discourse is that it is not solely critical of more recent development in biotechnology and other frontier agricultural research. Even the green revolution, the mythical success of international agricultural technology attracts its criticism:

> The new wheat (*Triticum aestivum*) and rice (*Oryza sativa*) varieties of the Green Revolution increased food production in Asia and Latin America and provided food for hundreds of millions of people, but also marginalized untold millions who lost their access to the land or their employment (Conway, 1997). Do all silver

> clouds have dark linings that we often don't perceive at first and certainly can't predict? (Chrispeels & Mandoli, 2003, pp. 6)

While critical of all utilitarian ethics, this discourse has received recent impetus from two separate developments: the advance of genetically modified organisms and climate change. The two phenomena are not necessarily perceived as interdependent, but they both offer an opportunity to recast the problem of science in agriculture on a worldwide scale. The increasing diffusion of GMOs, depending on a handful of varieties, concentrated in only three crops (corn, soybeans and cotton), appears to exaggerate and dramatize the traditional agricultural model: monoculture, the pesticide treadmill, favoring developed countries and large holders. In addition to these features, it also adds active challenges to ethical concerns in the form of massive risks: loss of biodiversity, contamination, displacement of traditional agriculture, dependence on profit making, ethically unresponsive, and perhaps irresponsible, multinationals.

Climate change adds fuel to ethical concerns by portraying incumbent scenarios of agricultural distress, where the adaptation capacity—which should be rooted in diversification of local varieties, cultivation practices, competences, and resources—is being jeopardized by the uniform prescriptions of modern technologies, including the ones inherited from the green revolution and, ominously, from the expanding frontier of agrobiotechnologies.

To summarize, the ethical narrative for agricultural science appears well in line with a critique of Bourdieu's "doxa", defined as *the fundamental, deep-founded, unthought-of beliefs, taken as self-evident universals, that inform an agent's actions and thoughts within a particular field.* The conventional narrative, in fact, sees the application of science to agriculture as plain and non-problematic in its commitment to increase food production. It also sees the application of technology to agriculture as a major hope for the future (scientific progress is seen as social progress, as in the modernist paradigm), in a positive and hopeful eschatology, regardless of its social and ethical form, the power relations among the various stakeholders and, in particular, the role of smallholders and developing countries. The contrarian ethical narrative, on the other hand, does not deny that science and technology may provide opportunities for development, but perceives them as a threat, to the extent that they promote a relentlessly commoditized model of agriculture and social life. As before, this narrative also proposes an eschatological view, albeit of a negative variety, enhanced by a sort of nostalgia for a golden age of "natural agriculture" and felicitous balance between nature and nurture.

These two positions are part of a moral and perhaps a political discourse rather than the object of a dispute on scientific truth. Thus, both discourses, as Foucault has aptly explained, represent the limit of acceptable knowledge within one cultural system. Being political, they are also, in some sense, inevitably in bad faith (Barthes, 1982), as they reflect the power relationships within the systems that express them. On the other hand, as Habermas (1995) forcefully asserts, moral theory is part of the emancipatory history of modernity, to the extent that it shows that the solution of the ethical dilemmas depends on the voluntary assent of all affected parties, thus, a public process of criticism and debate is the only credible form for the resolution of moral disputes. In this process, a key element of credibility may be injected by a change in the attitude of the scientists who operate in agricultural research. This would involve a major move from an attitude based on neutral predictions of ethically acceptable consequences to active commitment to pursue these consequences ("from predictions to promises," as Jeffrey Burkhardt, 2002, puts it). But also, the World Bank can—and appears to be willing to—play a role in this respect, as can be seen in its early attempt to find a balance between the two opposite narratives. For example, Ismail Serageldin, who was Chairman of the Consultative Group on International Agricultural Research (CGIAR), and Vice President for Special Programs at the World Bank, in an article on the June 1999 issue of Science, recognized that

> …agrobiotechnology research cites ethical, safety, and intellectual property rights issues. Protection of intellectual property rights encourages private sector investment in agrobiotechnology, but in developing countries the needs of smallholder farmers and environmental conservation are unlikely to attract private funds.... Biotechnology can contribute to future food security if it benefits sustainable small-farm agriculture in developing countries…. Public investment will be needed, and new and imaginative public-private collaboration can make the gene revolution beneficial to developing countries. This is crucial for the well-being of today's hungry people and future generations. (Serageldin, 1999, pp. 388)

More generally, the role of the World Bank in reducing the cognitive dissonance arising for the innocent

bystander from such contrasting ethical discourses can be seen as an integrator of denotation and connotation, as suggested by Roland Barthes (1982). According to Barthes, denotation implies that the meaning is directly suggested by appealing to facts, without invoking codes of interpretation, while connotation appeals to a reservoir of "stylized truths" to provide hints and clues so that the signified can be properly, and endogenously, "extracted" from the signifier by the onlookers. Rather than challenging the "facts" purported by each opposing narrative, the World Bank has wisely chosen to act by both investigating the "stylized truths" and by providing the appropriate embedding connotations. For example, in the latest World Development Report (World Bank, 2008), some ethically important stylized truths are recalled for future reference: the timeless importance of agriculture, its unique capacity to foster overall development, the success of Asian agricultural development and poverty reduction both in China and in India and, although for different reasons, the fact that the poor are overwhelmingly rural.

The Economic Problem

It may seem that the main problem with the social effectiveness and acceptability of agricultural science is its economic value. Cost-benefit analysis, after all, is the recognized way to proceed in the case of most large investment projects, especially those of public significance. Things are not so simple, however, and cost-benefit ratios of agricultural research remain controversial because of the essentially problematic nature of the identification and measurement of costs and benefits. As for the ethical discourse in this case, the conventional wisdom tells a story that sharply contrasts with the alternative radical narrative. Both for the "green revolution" effects of agricultural research and the more recent claimed successes of biotechnology, the story of unqualified and progressive yield increases is contrasted with a story of uneven, unstable, and circumscribed progress benefiting mostly medium and large farmers, and putting world agriculture on an unsustainable energy and pesticide incentive treadmill.

Quantitative studies of the effects of agricultural research are mainly presented by the advocates of the benevolent interpretation. In these studies, benefits of agricultural research are generally identified in monetary terms as increases in incomes or consumer surpluses consequent to the application of the technology that the research has contributed to discover and develop. Costs include direct research, development costs (and some imputed costs of permanent installations), and, sometimes, but not always, extension costs. Costs such as the training of researchers and the adverse consequences on other agents are also typically not accounted for. Market prices, rather than shadow prices and partial equilibrium analyses, are also generally used, and the counterfactual situation (i.e., the situation that would have been determined should the research have not taken place) is essentially identified with the status quo. Finally, neither risks undertaken and opportunities foregone are considered nor the irreversible nature of many resources committed to research or to the subsequent developments. Doubts about the orders of magnitude of economic returns reported in the literature derive also from the widely different methodologies, the confusion between nominal and real returns, the varying time lags, the differences between ex ante and ex post rates, as well as the systematic downward estimates from self-evaluation.

Furthermore, rather than basing the economic evaluation on average (or median) costs and benefits, modern economic evaluation should be based on the estimate of agricultural research impact on the contingent wealth of winners and losers (Pennisi & Scandizzo, 2006). In particular, the investment may destroy and create real options—i.e., a combination of capabilities and exposures to opportunities and risks—that have economic values that may go much beyond, both positively or negatively, the estimated aggregate income (or consumer surplus) increases in the average scenarios. These options include reduced or enhanced adaptability to climate change—a key factor for economic performance and perhaps for survival in the years to come.

Table 1 presents a summary of a major review of the evidence on this subject, i.e., the IFPRI meta-analysis (Alston, Chan-Kang, Marra, Pardey, & Wyatt, 2000). It shows that the range of magnitude of the estimates is extremely large, and that the average estimates most of the time fail to pass the test of statistical significance (i.e., the standard deviation is much larger than the average). Accordingly, the authors conclude:

> …Our purpose in conducting this study was to determine the information content of the rate of return evidence. One key finding is that there is much noise relative to signal (contrary to the conclusions of previous reviews, which stressed the central tendencies, concealing the noisy nature of the evidence). The study is useful in suggesting (and justifying) a degree of skepticism about the conventional wisdom and much

Table 1. Estimates of rates of return to research.

Attribute	Number of estimates	Average	Mode	Median	Minimum	Maximum
Rate of return						
Nominal	351	69.6 (64.1)	52.0	51.0	-2.3	466
Real	1,302	76.8 (145.8)	46.0	43.8	-100.0	1.736
Nature of evaluation						
Ex ante	405	93.7 (214.7)	49.0	35.9	-12.3	1.736
Ex post	1,367	77.4 (216.5)	46.0	46.0	-100.0	5.645
Average rate of return	1,708	81.5 (266.0)	49.0	38.0	-100.0	5.645
Marginal rate of return	686	80.5 (97.8)	40.0	50.0	-1.0	1.219
Benefit-cost ratio						
Reported	1,683	72.4 (190.5)	46.0	44	-100.0	5.645
Derived	89	246.7 (387.2)	1.4	60	0.3	1.720

Note. Standard errors are given in parentheses. Sample excludes two outliers and include only returns to research only and combined research and extension, so that the maximum sample size is 1.722. In some instances further observations sere lost owing to incomplete information on the Specific characteristics of interest.
Source: IFPRI (2000, pp. 70).

> of the specific evidence…. (Alston et al., 2000, pp. 81)

This conclusion seems to be an endorsement of the view challenging the official "power" story but, at the same time, by cultivating a language of precision and understatement (a "degree of skepticism"), appears to reject any support of the radical discourse.

IFPRI is part of the CGIAR, the international network of agricultural research centers sponsored by the World Bank. Its function can thus be seen as following the same broad strategy of reasonable interpretation and detached judgment about the evidence. Different from the ethical discourse, however, here the cognitive dissonance from the two opposite narratives on the economics of agricultural research is *reduced* by injecting the idea of impartial and scientific assessment of the evidence. A scientifically minded observer, it is suggested, should maintain a hopeful, but guarded, look on the size of net economic benefits delivered by science. The claim to specialized knowledge is thus authoritatively exercised to develop a discourse on the potential—and limits of—agricultural research, deflating both excessive pretenses of success and exaggerated accusations of failure.

The Ecological Problem

Since the publication in 1962 of Rachel Carson's "Silent Spring," environmental thinking has tended to reject altogether the traditional production paradigm governing the application of science to agriculture. The book persuasively argued that agricultural practices may not be sustainable because of their continuous damage to the environment and our health. While sustainability is a slippery concept, it seems clear that present agricultural practices are not sustainable, since they replace natural ecosystems with crop fields and tree farms (with accompanying loss of biodiversity and massive carbon dioxide release) and result in groundwater pollution, soil erosion, aquifer depletion, soil degradation, pesticide pollution, and other environmental stresses. Agricultural research, being guided mainly by the production paradigm, and increasingly dependent on profit-making investments of multinational companies, does not appear to be able to internalize this vision.

According to this line of thought, which represents a narrative directly challenging the story of agricultural

research as an environmentally friendly activity, sustainable and multifunctional agriculture should not only be about cheap wholesome food, but also about stewardship of the land, preservation of the resource base, the health of farm workers, the preservation of the small biota that are rich in biodiversity and are interspersed with fields, the value of rural community, and of the agricultural landscape. These objectives are especially important for climate change, where the capacity to adapt depends critically on the type of agricultural systems implemented.

The paradigm of sustainable systems does appear to be more in line with the increasing need to look at agriculture as a flexible set of opportunities rather than as a growing machinery for production. A wide variety of adaptation options has been proposed, for example, to reduce vulnerability to climate change, to help exploit the opportunities provided by increases in temperature or rainfall, or both. In general, scientists agree that agriculture can adapt to a moderate level of global warming (an increase of about 2.5° Celsius), even though adaptability would be higher for the Northern hemisphere, where climate change may provide opportunities for yield increases. Mendelsohn and Dinar (1999), for example, show that, given that adaptation occurs, increase in the average temperature would benefit US agriculture, even though, at the same time, increases of inter-annual variations would be harmful. For the Southern hemisphere, adaptability would be lower and climate change would be a threat, rather than a potential, albeit limited source of opportunities, since temperatures are already near their maximum tolerable heat level.

The World Bank, in making a major effort to take the lead in suggesting a course of action, intervenes with a soothing message. These problems, it suggests, are a source of only passing and apparent contradictions, because

> …tackling climate change requires **leadership, vision, capacity, and resources beyond the development experience to date.** Yet the transformation to a more sustainable development path has already started across the world. This transformation is driven largely by higher energy costs and growing concerns about adequate access to water, land, and mineral resources to support growth and livelihoods. It is facilitated by an increasing value of a healthy and productive environment, and a stronger voice and participation of the civil society. (World Bank, 2008, p. 203)

Clearly, climate change may be creating its own set of economic tales, but the ensuing discourse suggests new boundaries of conceivable knowledge and, as such, may be pointing to a newly established frontier for thought on scientific development. The underlying narrative that the World Bank is developing in order to quench the cognitive dissonance in this regard is clear: climate change is the new prevailing force to reckon with in the field of agricultural development. It is already upon us, so that not only mitigation efforts are necessary, but also adaptation actions are inevitable. Research in agriculture, however, may be inadequate to fulfill the task of offering new choices and new solutions to the problems created by climate change because it has taken an altogether different direction: the pursuit of profit-maximizing micro-agricultural improvements within the single integrated agro-industrial enterprise in a context of thoroughly protectable property rights on innovation. A radical change is thus needed to proceed from narrowly defined, profit-oriented, short-sighted, privately dominated agricultural research to a pursuit of knowledge truly attuned to the planetary adaptation facing humanity and agriculture today.

Agro-biotechnology: A Promise or a Threat?

The current social discourse about agro-biotechnology (ABT) reflects, to an extent, the dichotomy between the conventional mode of thinking and the radical critique. At the same time, because of the high level of information bias and uncertainty, it seems dominated by a more academic debate on the nature and extension of social risk. At one extreme, there is the pure probabilistic position. This position maintains that the essence of the argument on biotechnology is probabilities: the probabilities of technological breakthroughs and, conversely, the probabilities of environmental and health damages. The unstated, underlying narrative seems to be that mankind progresses only by taking chances of both successes and dangers, no matter how large the latter may be in the worst possible scenarios. At the other extreme lies the full contextualist position, maintaining that what matters is a vector of characteristics (productivity, familiarity, friendliness to the environment, favor for the poor, adaptability, etc.), with probability being only one of these qualities. According to the contextualist narrative, communities may object to change, on the basis of

habit, social order, ecological balance, aesthetic harmony, as well as uncertainty and lack of structured information. Generally, advocates of the two points of view find it difficult to communicate, as they select evidence to corroborate their approach or, sometimes, "…present selected aspects of the data both for and against transgenics, precluding a fuller discussion of the issue" (Pehu & Ragasa, 2007, pp.1-3).

A probabilistic discussion of ABT prospects is presented in the 2008 World Development Report and some related papers (Pehu & Ragasa, 2007; World Bank 2006a, 2006b). Narratives that represent this view are elaborated, claiming that the evidence shows that ABT has already achieved a significant degree of success, although adoption of transgenics mainly concerns a few crops (cotton, corn, and soybeans) and large landholders in developed countries. Moreover, the demonstrated environmental and health impact is positive, largely because of the reduction in the use of pesticide, but the need for continuing monitoring of possible negative effects is still high. Progress for food crops relevant to the poor is slow, and potential problems arising from lack of infrastructure, weak institutions, and the preponderance of privately driven research in developing countries may be serious. Nevertheless, concludes this story line, the potential of ABT appears so large that every effort should be made to channel agricultural research in its direction and, at the same time, in the direction of poor consumers and small farmers in the developing world.

An example of the contextualist position is given by Ervin, Batie, Carpentier, and Welsh (2001), who claim that a precautionary approach to ABT is in order because environmental changes are unpredictable, invaluable, irreversible, and nonlinear. Thus, our interaction with environmental variables reveals a somewhat futile attempt to tackle variables whose reaction and evolution are a continuous source of surprises.

These propositions summarize what might be called the "moderate view" among contextualists. More radical positions are, however, entertained by a variety of social and biological scientists. For example, a discourse on the relationship between behavior and power concerns the progressive concentration of the agrochemical industrial complex (Magdoff, Foster, & Buttel, 2000). This discourse represents ABT as no more than a tool to put the farming sector—and in perspective also the small farmers in developing country—at the mercy of commercial agriculture and, in particular, of the multinationals. Profit-driven conglomerates, according to this view, are constitutionally oriented toward integrated and homogenous technological packages that can bolster commercial crops, rather than improve the satisfaction of basic needs. Moreover, in their quest for ever-increasing power, they tend to appropriate a large part of the gains and polarize economic activity among a small number of winners and a large number of losers, thus creating marginality and social exclusion on a grand scale.

The contextualist view can be also interpreted as a catastrophic narrative of globalization, where a cultural objection to ABT is advanced both as a symbol and substance of a much feared dilution of local customs, prospects, and values into a new form of global economic and cultural soup. This kind of narrative arises extraordinary feelings of insecurity and denial against transgenic organisms since they are taken to promise (or threaten!) to go beyond the boundaries of ordinary science, and even of ordinary life; at the same time, they appear the elective symbols and testimonials of a new form of social order. As Mary Douglas (1966) persuasively argued, feelings of insecurity and the very perception of risk should alert us to the presence of perceived changes in social relations rather than to any specific physical or economic danger. Attitudes of rejection and denial that GMOs continue to arise, especially in developed countries, may thus be signs of perception of real impending danger, not necessarily to human health or the environment (although this cannot be excluded), but rather of a social nature, from a radical new form of the production process, where the genetic material becomes itself an input in a new, globalized and integrated value chain, with decreasing room for peasants and local production systems.

Multinationals and Biotechnology

The story of ABT intersects with the story of the multinationals in the food and pharmaceutical sector (FPS) in a way that can be taken as exemplary of the ambiguities and the social problems surrounding agricultural research. A conventional narrative on the evolution of the FPS multinationals takes the detached view that this is only an episode in the evolution of industries whose economies of scale constitute a continuous inducement to seek concentration and monopolies. A Coasian Narrative (Coase, 1937, 1988) suggests that multinationals emerge from the chaos of competition to increase efficiency by saving on transaction costs. Narrating the same story from a more critical point of view, however, may take the following form, which, though not necessarily inaccurate, is nevertheless suggestive of a differ-

ent interpretation. At the end of the 70's, a plurality of small specialized companies appeared to play a key role in the development of new techniques and products in the broad field of biotechnologies. The growth of new firms was especially high at the beginning of the 1980's when the researchers, who had made the fundamental discoveries in the field, started new companies to commercially apply their findings (Fonte, 1988). However, these small companies soon encountered financial and organizational obstacles (product distribution network); many of them were acquired by the large chemical and pharmaceutical multinationals, which, in the meantime, had started internalizing biotechnological research. These companies started, between the end of the 1980's and the beginning of the 1990's, a strategy of consolidation through a series of acquisitions and fusions aimed at unifying under the control of a single firm activities in the medical, pharmaceutical chemical, and agricultural field. At the base of these strategies was the diffused conviction that knowledge complementarities would allow the exploitation of large economies of scale and scope, but also, paradoxically, the fact that the growing regulatory hurdle was itself a barrier to entry to all but very large enterprises.

In the field of agriculture, it was clear from the beginning of the development of biotechnologies that the most convenient way to arrive at the market was through seeds. To ensure access to the market for seed has constituted the motor of a wave of fusions, acquisitions, and agreements that have, to this day, left on the scene only six great actors, who are, at the same time, leaders in the agro-chemical and seed sector.

The processes of horizontal and vertical integration with the seed industry have been favored, therefore, by strategies aimed at taking the maximum advantage from the complementarities that are created from the resources produced by the biotechnologies. During the 1990's, the first biotechnological products for agriculture arrived at the market, but industry found itself in front of a consumers' rejection of the new products. Social opposition was so strong that large companies were forced to continually modify their strategies, separating the pharmaceutical from the agrochemical divisions. At the end of 1999, AstraZeneca PLC and Novartis AG decided to operate a merger of their agrochemical divisions, constituting Syngenta, with a priority in the programs of genetic and agro-genomic technology. In the same period, Monsanto and Pharmacia & Upjohn announced the creation of a joint venture in the pharmaceutical field, which will maintain the name of Pharmacia, while the Monsanto brand remained exclusively tied to agrochemical activities (of which, in any case, Pharmacia holds 85% of capital). Aventis also generated Cropscience, which was acquired by Bayer in March 2002. In the agrochemical field, the new strategy of the companies that have been reorganized according to this model, is downstream vertical integration of the agro-food value chain. Within this framework of colonization of the entire sector of food production, it is possible to read the meaning of some important strategic alliances: Monsanto constitutes a joint venture with Cargill, called Renessen LLC; in 1999 Monsanto reaches an agreement with Conagra to segregate and commercialize transgenic products in the countries willing to accept them; and in 2002 Monsanto announces an agreement with Dupont to share patent protected biotechnologies (ETC Group, 2002).

The strategy adopted and all these agreements, however, reveals a basic weakness that depends on the very characteristic of research as a (latent) public good. Patenting the genetically modified seed, in fact, tends to be ineffective and, where limited effectiveness is exhibited, threatens the agricultural practice of replanting the seed obtained from the previous harvest. Once the farmer chooses to adopt the transgenic plants, he effectively makes an irreversible decision: transgenic plants in fact, through cross impollination, also transmit their genes to the non-transgenic varieties in the neighboring areas and, sometimes even to those in areas very far away. Transgenic plants, therefore, present a major contamination problem, which is becoming one of the largest cases of negative externalities for farmers that have chosen *not* to adopt the new technology. Aside from the costs from irreversibility, damages are particularly serious for biological products, for which farmers face denial of certification in the case of GMO contamination. International property rights laws thus protect multinationals from unauthorized usage, but do not equally protect farmers from contamination.

The World Bank narrative in this respect is interesting, in both its recognition and understatement of the problem. In the only reference to the multinationals in the World Development Report (World Bank, 2008, pp. 158), we read:

> Consider the win-win-win case of transgenic insect-resistant cotton: it has reduced yield losses, increased farmer profits, and greatly reduced pesticide use for millions of smallholders. But the benefits of biotechnology, driven by large, private multinationals interested in com-

mercial agriculture, have yet to be safely harnessed for the needs of the poor.

Conclusions

For agricultural research, the fact that narratives dominate the debate on scope and achievement is somewhat paradoxical, since research is committed to a rigorous methodological approach and is accountable to a scientific community, which should have little propensity to listen to the sirens of the rhetorical discourse. The highly formal nature of the scientific method and the prudence and the caveats that surround all the specific achievements of science, however, may themselves be the source of a peculiar vulnerability, when a comprehensive view of successes and failures, as well as meanings and scope are called for. The discourse about science may thus turn out to be rather un-scientific, involve prejudices, exaggerations, and controversies, and use narratives as the main vehicle of elaboration and understanding. By their very nature, these narratives will tend to dramatize the events and attempt to convey messages that may be considered extreme, either in defense of the status quo or against it.

A provocative way to interpret this state of affairs is provided by the idea that narratives are simply the side effects of technological change and this, in turn, is merely the consequence and not the cause of social change. If this is true, narratives are no more than ways by which social change anticipates and rationalizes technical change, through the predisposition of a social machinery capable of engendering the innovations required. Thus, for example, the space race of the 1960's was the consequence of a heightened cold war, and the narratives on the superiority of one or the other superpower were only part of the process of communicating this conflict to the ordinary citizen. Analogously, the biotechnological revolution, if it is indeed in the making, would be the consequence of a major re-organization of the structure of production, input provision, consumption patterns, and balance between private and public research, which is also already in the making. If this is true, the opposed narratives that are being deployed by different social groups are only the reflection of the conflict between those who feel that they are engendering the change and those who fear that they would be excluded or emarginated by it. The drama and the rhetoric of the competing narratives is due to the fact that this preventive lining up of winners and losers occurs in a transitional situation, where the impending social changes are still unclear and unclearly related to corresponding technological changes.

In this context of uncertainty and dynamic change, widely different interpretations of current events are possible, while the underlying structure of society is shifting in an unpredictable way. Different narratives summarize the attempts at explaining what happens by using a linguistic process formed by plots, heroes and anti-heroes, and, at times, pathos and drama. Because of its standing in the international community as a unique institution with financial, scientific, and moral authority, the World Bank appears to have chosen, alongside its traditional mission as a policy advocate for development, the role to provide comfort and guidance, thereby attenuating the cognitive dissonance arising from highly contradicting stories on themes such as development, research, science, climatic change, and, ultimately, human destiny.

By using a panoply of policy—divulgatory documents, epitomized by the influential World Development Report—the World Bank provides its own set of narratives. These narratives tend to coalesce around the underlying story of the ascent of men throughout the ages by the force of their imagination and concerted efforts, but go much beyond a mere reiteration of this theme. By appealing to a wide repertoire of in-house-researched, stylized truths, they elaborate on the role and the accomplishments of large numbers of unknown and reluctant heroes: the scientists, the innovative farmers, the adapting poor. In the case of science and agriculture, they provide, in a cautious and critical way, much needed policy advice on the future course of agricultural research.

Such policy advice has to be somewhat distilled from the very complex and cautious narratives provided, but it can be summarized as a serious attempt at looking for a balance between the conventional and the radical views. Its main points are three. First, rather than concentrating on marginal innovations for a handful of commercial crops, biotechnological research in agriculture should be directed mainly at seeking a viable alternative to the present energy-intensive modes of production in agriculture. Second, it should take smallholders and local production systems as the main targets for its applications and try to build new varieties less dependent on fertilizer and insecticide inputs—and at the same time, more integrated with, rather than being alternative to—the various cultivation options (rotation, multiple cropping, use of biological pesticide control) of small farmers around the world. Third, because this challenge requires the commitment of large amounts of

resources without the prospect of immediate gain, this type of research can only be undertaken by the public sector. Moreover, it can only be undertaken if the international community recognizes this conclusion as the major challenge for development and the reduction of poverty in the years ahead.

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