The Coming Revolution of Biotechnology: A Critique of Buttel

Gerardo Otero

Sociological Forum, Volume 6, Issue 3 (Sep., 1991), 551-565.

Stable URL:
http://links.jstor.org/sici?sici=0884-8971%28199109%296%3A3%3C551%3ATCROBA%3E2.0.CO%3B2-%23

Sociological Forum, Vol. 6, No. 3, 1991

Notes and Insights

The Coming Revolution of Biotechnology: A Critique of Buttel

Gerardo Otero[1]

Frederick Buttel was one of the pioneers in studying the social impacts of biotechnology, claiming originally that it will involve profound changes in social structure. Recently Buttel turned around his argument proposing that, rather than revolutionary, biotechnology is more a "substitutionist" technological form to be applied to declining sectors of the economy than an "epoch-making" technology. This paper provides both external and internal critiques of Buttel's new position based on the concept of the "third technological revolution," looking at the impact of new technologies as a global and interrelated phenomenon, and not on an individual case-by-case basis. The concluding section suggests the necessity of bringing into the analysis those living in the Third World: 60% of this population lives from agriculture and will be affected by the deployment of agricultural biotechnologies, whether through "substitutionism" or through totally new products.

KEY WORDS: agriculture; capitalism; development; world economy; Third World; genetic engineering.

INTRODUCTION

For several years, social scientists, policymakers, and biological scientists have regarded biotechnology as one of the new techniques that would revolutionize production in medicine and agriculture. More recently, however, one of the very pioneers in the study of socioeconomic impacts of biotechnology has turned the argument around (Buttel, 1989a). Rather than revolutionary, Frederick Buttel has proposed that

[1]Department of Spanish and Latin American Studies at Simon Fraser University, Burnaby, British Columbia, Canada, V5A 1S6.

0884-8971/91/0900-0551$06.50/0

biotechnology is more a "substitutionist" technology to be applied in declining sectors of the economy. For these reasons, he has argued that biotechnology should no longer be considered an "epoch-making" technology as are electronics and informatics.

The first section of this paper is dedicated to a presentation of Buttel's arguments. In the second section I provide both external and internal critiques of Buttel's position based on a different perspective, which uses the concept of the "third technological revolution." One of my central contentions in this regard is that the appropriate way of dealing with new technologies is by looking at their impact as a global and interrelated phenomenon, and not on an individual, case-by-case, basis. Finally, the concluding section suggests the necessity to bring into the analysis the majority of the world's people: those living in the Third World. I present some research questions and hypotheses on the potential regional implications of biotechnology in these societies. Whether directly or indirectly, Third World populations are bound to be the most affected by the deployment of agricultural biotechnologies.

IS BIOTECHNOLOGY REVOLUTIONARY? BUTTEL'S ARGUMENT

Although the very definition of "biotechnology" has been the subject of controversy, I base my discussion on one provided by the General Accounting Office (GAO) of the U.S. Congress: "Today, biotechnology is generally considered to be a component of high technology, and the 'new biotechnologies' are those resulting from recently developed, sophisticated research techniques, including plant cell and protoplast culture, plant regeneration, somatic hybridization, embryo transfer, and recombinant DNA methods" (GAO, 1986:10). In my view, biotechnology is possibly the most important technical force that will shape world agriculture over the coming decades. But biotechnology is a two-edged sword. Which way it cuts will depend largely upon who wields it and how (Kloppenburg, 1988; Kloppenburg *et al.*, 1988).

Buttel, however, has become impatient with biotechnology. In the few years since he and his colleagues began to examine the potential impacts of new technologies (Buttel *et al.*, 1985), there have not been any major changes in the agrarian social structure or productivity due to biotechnology. Therefore, Buttel (1989a, 1989b) has declared that biotechnology is not a revolutionary or epoch-making technology.

It was interesting to read what I thought was largely a "devil's advocate" paper, arguing against positions that Buttel himself had advanced in

the past. The initial argument for toning down the extent of biotech's impact was Kenny and Hibino's paper presented at the 1987 meetings of the Rural Sociological Society. Both papers can be seen as self-criticism of previous work, an activity that is usually healthy. And yet Buttel's paper overcompensates. Because my own work on biotech has been influenced by the critical scholarship represented by Buttel's work, I cannot agree with his new position.

Buttel's strategy to declare that biotechnology is not a revolutionary or epoch-making technological form is *ad hoc*. First he sets three criteria, all of which have to be fulfilled by any given technology if it is to be labeled "revolutionary." He admits that it is a fairly arbitrary set of criteria, but posits it as a framework to provoke discussion. The first criterion is that the technology must have a wide applicability. The second is that it should be applicable to production, as a cost-reducing technology, as well as to consumption, in creating large new categories of consumer and producer goods. Third, applicability should be directed to leading or ascendant sectors of the economy.

Once these criteria have been set, Buttel goes on to establish why, in his view, biotechnology does not fulfill them adequately. First, Buttel argues that while biotechnology will have wide applicability, it will only "patch up" problems of Western agriculture. An example of this would be the creation of herbicide-resistant plant varieties. But this general assessment of biotechnology is done on the basis of regarding it a "substitutionist" technology, following Goodman and colleagues (1987). Buttel provides no reasons why substitutionism will not create major changes in productivity and social structure.

A second disqualifying factor against biotechnology is that, in Buttel's view, it will be applied to declining sectors (agriculture and manufacturing), rather than to the leading or ascendant one (services). Services is regarded as the leading sector in "postindustrial" societies, although this characterization of present capitalism is not discussed. Because of this, biotechnology is regarded as a "subsidiary technical form." Unlike microelectronics and associated information technologies, biotechnology's "application to services will probably be confined to health services," says Buttel (1989a:254). Buttel is right when he says that medicine or health services will be affected by biotechnology. And if we take into account health care's current proportion in the gross domestic product (GDP) and the fact that it is increasing faster than any other category, there is no doubt that biotechnology will have a substantial market. In fact, one of the recent concerns of "corporate America" is that the costs of medical care are soaring — and are now over 10% of the GDP (Garland *et al.*, 1989). Thus, even if biotechnology were to be "confined" to health services, it would have

great potential. And pharmaceuticals are only a small piece of future products in human genetics.

Buttel gives two other reasons against considering biotechnology as revolutionary. In his view, biotechnology was "prematurely commercialized, and its major applications lie decades ahead into the future." Moreover, he argues, "the historical . . . patterns of investment in biotechnology have been highly speculative and often 'defensive' in nature" (1989a:256). Based on these observations, Buttel considers that the biotechnology industry faces not transformation — but rather imminent decline.

EXTERNAL AND INTERNAL CRITIQUES

As an external critique of Buttel's analysis I question the very premises of his formulation of the research problem. My task in the internal critique is to assess Buttel's internal consistency in his use of concepts, and whether his substantive propositions are actually backed up by available data.

On the external level, I find Buttel's "problem" rather problematic. It is a false problem to ask whether biotechnology is revolutionary or not. It would be quite difficult to establish consensus on basic criteria by which to judge what is revolutionary or epoch making, and what is not. More importantly, we must ask first whether there is a third technological revolution within a long-wave movement in effect (Mandel, 1978, 1980). Is this new revolution — based on electronics, informatics, new materials, and biotechnology — actually leading to a new phase of capitalism? If we can answer this affirmatively, then we could ask what is the place of biotechnology in such revolution and in reformed capitalism. In the context of these questions it would be misleading to ask whether one of those new technologies, individually, is epoch making or not. In sum, we should keep the question of the third technological revolution conceptually as a single phenomenon, rather than as one made up of several juxtaposed revolutions based on each of the new technologies. While it is clear that the new technologies have different rhythms of development, with electronics in the leading position, there are at least two reasons why we should consider them as a conceptually single phenomenon.

First, the combined use of two or more of those technologies in new productive processes generates tremendous "synergies." The successful use of certain innovations may actually pose the technical requirement to combine the use of two or more of the new technologies. For instance, the most sophisticated dairy operations may use embryo transfer technologies

to improve the herd, while using computers to maintain exact yield records per cow and to monitor their feed requirements (Sun, 1986:151). Second, capitalism as a world economy entered a period of profound crisis in the early 1970s (Mandel, 1978). Its development had been based on heavy industry, which is indeed declining or being profoundly restructured (Piore and Sabel, 1984). The current restructuring of the world economy is predicated on productivity increases, which in turn depend on new technologies (Hastopoulos *et al.*, 1988; Young, 1988; Florida and Kenney, 1990). Mandel has convincingly demonstrated the existence of "long waves of capitalist development" (1980) and predicted an upswing of capitalist growth in the early 1990s. Therefore, engaging in a partial analysis of whether one or the other new technology is revolutionary can only be misleading. The task at hand, for development sociology at least, seems to be in decoding the implications of the "reformation of capitalism" (Sklair, 1989) for the new international division of labor.

An internal critique of Buttel's analysis will further highlight the need for a different perspective. Out of the three criteria that he proposes, Buttel concludes that No. 3 is the one biotech least fulfills: it is not applicable to leading or dynamic sectors, but to declining ones. It is mainly this limitation of biotechnology that Buttel sets out to establish in his paper. His claim that biotechnology does not meet the third criterion is based on three arguments: (a) it is a substitutionist technology both in agriculture and the pharmaceutical industry, so that it will only patch up the problems of Western agriculture and medicine; (b) the initial research may have been oriented toward revolutionary goals (e.g., the nitrogen fixation agenda), but these have been abandoned in favor of short-term commercial and profit interests; and (c) biotechnology is applicable to declining sectors (manufacture and agriculture), and the biotechnology industry itself is declining, evidenced by disproportionately poor performance of biotech stocks in the Black Monday crash of 1987, and the reduction of in-house biotechnology research in large chemical and pharmaceutical firms.

Substitutionism

Buttel tends to minimize the importance of biotech on the grounds that it will merely *substitute* existing products. I think, however, that this may be just the beginning of the application of new techniques, but they offer virtually endless possibilities. Even confined to a substitutionist role, biotechnology could have profound implications for both productivity and the international division of labor, which are bound to generate major so-

cial changes. In fact, some have already occurred with the introduction of high fructose corn syrup in the United States. From 1978 to 1987, 42% of sugar used in the United States was substituted by the new sweetener based on corn and produced with new enzymatic techniques. This change was profoundly damaging for several Caribbean countries and the Philippines, for a large part of their foreign exchange came from sugar exports to the United States (Ahmed, 1988; Otero, 1989a). Current research in Germany is developing a substitute for coffee (Quintero, 1989). How will that affect the economies of several Central and South American countries for which coffee is a major export crop? Will they continue to shift production from basic to illegal crops? To be sure, mere "substitutionism" can have profoundly damaging effects on countries exporting primary goods. On the other hand, scientists can currently do more with biotechnology than their sciences allow them to understand. In other words, the technology is more advanced than science in this case, as far as knowledge and understanding of certain processes goes. The new techniques may eventually serve creative minds to develop more revolutionary products than mere substitutes for presently existing ones. Now, is it a question of time? Sure, but Buttel's criteria for defining what is revolutionary do not establish time limits, which would be quite arbitrary anyway. Thus, whether through substitutionism or new kinds of products and processes, biotechnology holds a tremendous potential for promoting major changes in production structures.

Research Agendas

Although Buttel does not define "revolutionary research agendas," one might infer that they result in new products that go beyond substitutionism. These would include new categories of goods and processes that will create equally new markets for means of consumption and means of production.

With this definition in mind, whether or not revolutionary research agendas have been abandoned is more of an empirical question. Buttel asserts that such agendas have been abandoned, at least in the industry labs. While this might be true for the most part, there are many university labs that may be doing very significant "basic" research that may sooner or later become "applied," as has happened in the past in various biotechnology-related disciplines. Mexico has a whole research center dedicated to nitrogen fixation research at the National Autonomous University of Mexico, and its researchers are in the frontier of knowledge, publishing in respected international journals and beginning to establish links with industry (Otero,

1989b). Nitrogen fixation is one of the areas of research that Buttel explicitly regards as revolutionary.

The whole issue of research agendas is one that may change rapidly with the intervention of the U.S. government. During Ronald Reagan's administration there were two areas of legislation that were reoriented to enhance the commodification of science: P.L. 96-517 (enabling universities to patent federally funded research results), and the new possibilities of patenting plants, microorganisms, and animals. There is a current debate in which a strong (perhaps official) position is questioning the Mertonian conception of science, discipline-based research, and the peer review method of allocating funds, favoring a more pragmatic approach that talks about establishing "strategic priorities" and interdisciplinary research. In fact, there have always been priorities in allocating federal research funds in the United States, with the Department of Defense usually charged with allocating the largest piece of the pie (66% in 1987). But nondefense federal research funds have been largely allocated according to the peer review process. If this changes, biotech research could go in either of two ways: orienting research agendas toward human needs or toward the interests of transitional corporations and the state's interest in making the U.S. economy more competitive at all costs. The National Science Foundation has taken a step in the latter direction by creating interdisciplinary research centers. While I ignore the particulars about how they are being established, these centers get funds outside of the usual peer review process, at least to get them started. Also, I suspect that they are very clearly "mission oriented" with strategic priorities in mind. The latter may well include research agendas that Buttel would call "revolutionary" for biotechnology, even if most are geared to the perceived need to take knowledge to the marketplace as quickly as possible.

Declining Sectors

Macroeconomic theory has used the concept of sectors to categorize the various parts of the economy into more or less homogeneous groups: the primary goods producing sector (agriculture, mining, oil, etc.), the secondary sector (or manufacturing or industrial in a strict sense), and the tertiary sector (services; this is perhaps the most heterogeneous). In terms of employment, the tertiary sector has been the most dynamic in the United States, but in productivity growth the manufacturing sector has been more dynamic. Baumol has effectively questioned the "deindustrialization of America" thesis. That manufacturing absorbs a lesser proportion of the labor force does not indicate that it is declining. To the contrary, it means

that its productivity is quite dynamic: "throughout the industrial world . . . productivity in manufacturing has grown considerably faster than it has in a large group of services . . . This means that, though manufacturing outputs have grown, less and less of each nation's labor force has been needed to produce them" (1989:612).

One can certainly break down the analysis of sectors, and this is done by "industry" — and here, even agriculture would be considered an industry. In Buttel's article, "industry" and "sector" are confused when he mistakenly refers to the pharmaceutical "sector" as a potentially dynamic one. Strictly speaking, pharmaceuticals are an industry. It would have been much better for Buttel's purposes to talk about "industries" in his third criterion, rather than about sectors, because the latter concept is much too general and may contain very heterogeneous industries in terms of their dynamism.

Now, is agriculture a declining industry? Buttel answers "yes," against the empirical evidence. Whether we call agriculture a sector or an industry, its productivity has been historically quite dynamic, indeed surpassing the rest of the economy in its productivity (measured as output per unit of labor) rate of growth (National Research Council, 1989:33). What has happened though, as in manufacturing, is that a far smaller number of people are able to produce enough food to feed the United States *and* to have an exportable surplus. In fact, in the last few years when the U.S. economy has been losing competitiveness in world markets, manifested in a growing trade deficit, agriculture has been the only sector that has accounted for a significant trade surplus of about $13 billion (National Research Council, 1989:30–32).[2]

Thus, how do we measure "dynamism?" By production and productivity increases, or by the proportion of the labor force absorbed by an industry or a sector? If the latter is taken as a measure, which is what Buttel seems to have done implicitly, then indeed "services" would be the most dynamic sector, with 66% of the U.S. labor force in 1980 (Baumol, 1989). But this is problematic for several reasons: it would be a major inconsistency with the designation of the "Green Revolution" as a package of revolutionary technologies, and it would be unclear why electronics and informatics should be considered epoch-making technologies by Buttel's account.

[2]"Agriculture" is used here in a restricted sense, as equivalent to farming. A broad definition of agriculture would include the agricultural inputs industry and the food processing industry. Biotechnology will have an impact on both in important ways. For instance, new plant varieties with herbicide resistance will expand the sale of inputs, and new tomatoes with greater solid contents will increase the profitability of food makers. On the other hand, the environmental implications of the former trend may be largely undesirable (Otero, 1990).

"Green Revolution" (GR) was the name given to the technological package behind the modernization of U.S. agriculture, which was exported to Third World countries in the 1960s and 1970s. But its application in the United States began in the 1930s, with the introduction of improved corn varieties, namely hybrid corn. Later on came other improved varieties, chemical fertilizers, pesticides, herbicides, and increasingly sophisticated agricultural machinery. As a package, these technological innovations not only gave a tremendous boost to productivity; they also displaced large numbers of farmers from their occupations (Cochrane, 1979; Kloppenburg, 1988). If anything, the so-called GR accounted for a major leap forward in agricultural productivity. But it is also one of the major factors in the dramatic reduction of the labor force dedicated to farming, now a mere 2.2% in the United States.

In Third World countries where the GR was adopted, the negative socioeconomic consequences were much graver. It was regionally polarizing, favoring zones with irrigated agriculture, and it entailed profound social differentiation processes, by which the better-off farmers benefited disproportionately and poor farmers went out of business, due to the scale bias of GR technologies toward large farms (Cleaver, 1972; Hewitt de Alcántara, 1978; Pearse, 1980). Environmentally, there have been many problems of ground water pollution, soil erosion, loss of genetic diversity, and increased crop vulnerability resulting from cultivation of increasingly homogeneous plant varieties (Kloppenburg, 1988; Otero, 1991). All of these problems appeared in the United States as well, but Third World countries were in a much more vulnerable situation: they were not undergoing the robust process of industrialization that the United States was experiencing after the 1930s. Hence the results were more dramatic in the underdeveloped world: there were massive migrations to the cities where too few employment opportunities could be found. Then the tertiary sector began to grow rapidly in underdeveloped countries. But this was certainly not a sign of dynamism of the sector; rather, it masked severe unemployment and underemployment of people who had been displaced from agriculture. I doubt that Buttel wants to refer to this type of dynamism, but his arguments lend themselves to this interpretation.

Is the biotechnology industry declining too? As may be expected from the foregoing, Buttel would also answer "yes" to this question in a twofold sense: the biotech industry is declining both in the stock market, and with regard to the amount of research and development conducted in-house.

It is true that many biotech firms suffered disproportionately in the Wall Street crash of 1987. While the overall decline in stock prices for the 400 largest companies in the United States between the 12th and the 28th

of October was 28%, the dip in stock prices for 60 prominent biotechnology firms was 44% (Crawford, 1987). But should not these financial difficulties be attributed to the infancy of the new industry, and to the fact that it has taken longer than expected to come up with commercial products? If anything, such difficulties will accelerate the concentration trends in biotech. In fact, Genentech, the flagship firm of the industry, has recently been taken over by Roche Holding Ltd., the Swiss parent of giant drugmaker F. Hoffman–La Roche & Co. (Hamilton *et al.*, 1990). This could set off a shopping frenzy by the giant TNCs for small biotech firms in the chemical and pharmaceutical industries (Peterson and Armstrong, 1990).

Jumping to the conclusion that biotechnology is a declining industry due to a conjunctural crisis resembles the "short-termist" mentality of which U.S. corporate executives are accused, when compared with their Japanese counterparts. A recent survey of 480 biotechnology firms (almost half of the approximately 1100 in the United States) found a healthy industry. Sales in 1988 were 33% higher than in the previous year, and the total assets expanded by 6%. The biggest concern expressed by executives was financial: whether they would have the ability to finance growth and technology development. Therefore, 66% of the biotech companies expect to be acquired by large firms at some point in the 1990s (*Genetic Engineering News*, 1989:11). This financial mechanism clearly reinforces the concentration trends.

With regard to research, reducing "in-house" efforts does not amount to withdrawing from research altogether. To the contrary, it probably means making a more efficient use of research and development funds, by contracting with universities. For example, Monsanto corporation, a giant in the agrichemical industry with substantial interests in biotechnology, fired over 100 biotechnology researchers in 1986; but it simultaneously gave a $60 million grant to Washington University for research in the same field. Such increased university–industry links are amply documented and represent a new type of relationship in the biological sciences (Blumenthal *et al.*, 1986; Kenney, 1986; Kleinman and Kloppenburg, 1988; Otero, 1989c). In sum, we cannot jump to the conclusion that the biotechnology industry is declining and withdrawing from research solely on the basis of a conjunctural business downswing and a shift in research policy.

CONCLUSIONS: BRINGING THE MAJORITY OF THE PEOPLE IN

My main conclusion from the foregoing analysis is that we gain a deeper understanding of complex events by considering biotechnology as

part of the third technological revolution. To the extent that new technologies are at the core of the world economic restructuring, biotechnology will play a major role in transforming agriculture. Just as the substitution of the horse for the tractor was revolutionary by any standard, biotechnology's substitutionism will bring about major changes in production and social structures. To be sure, these will not come overnight, for we are dealing with a *technological* revolution. Besides substitutionism, genetic engineering is leading scientists and industrialists to reconceptualize *what life is*. We are only beginning to see its potential. Like the Copernican revolution, biotechnology will lead to unforeseen developments.[3]

Moreover, the biotechnology industry itself has to be reconceptualized. Taken as individual firms, biotechnology companies have seen an expansion in sales and investments after recovering from Black Monday. Due to short-term financial problems, however, they are losing their independence and being integrated into industries that will use their technology. Thus, rather than an industry, genetic engineering will become an enabling technology for the already existing chemical and pharmaceutical industries. In fact, giants in these industries have been particularly aggressive in absorbing former biotechnology start-ups — and both of those industries present highly concentrated profiles. This emerging market structure will undoubtedly have a major bearing on the ways biotechnology products are disseminated in the world. The contrasts in this regard with the GR, which was promoted by public and semipublic institutions, will be profound.

Although the bulk of biotechnology research and development is taking place in advanced societies, deployment of its fruits will have implications for the world economy as a whole. As Iftikhar Ahmed has recently suggested, the "application of biotechnologies to agriculture would automatically affect 60 per cent of the Third World population who depend on agriculture alone for their livelihood" (1989:553). There have been important reflections on the implications of current changes for advanced capitalist societies, such as that by Piore and Sabel in *The Second Industrial Divide*, but few address the place of Third World countries in the new international division of labor. Given the vast heterogeneity existing among Third World societies, they will be affected differentially by the third technological revolution, depending on the profile of their socioeconomic structures. Some have recently become industrialized, precisely on the basis of new technologies. The larger countries have a certain potential to jump on the bandwagon of the technological revolution; others might be integrated to the world economy simply as producers of cheap labor power;

[3]I thank Martin Kenney for this idea in his comments to a previous version of this paper.

while still others could be marginalized from the main economic trends. Thus, one thing that should be looked at more closely is the new stratification of underdeveloped societies that is bound to emerge. An initial formulation has been provided by Castells (1986).

Castells proposes that a first stratum of Third World countries is made up by the so-called newly industrialized countries, currently Singapore, Taiwan, Korea, and Hong Kong. Their export-led industrialization has been predicated mostly on local capital, which accounts for up to 75% of total exports. Another stratum would be made up by those countries characteristically in the "new international division of labor" (Fröbel *et al.*, 1980). The countries included in this stratum are becoming mostly export platforms for the most labor-intensive parts of global labor processes within transnational corporations. Included in this category are Thailand, Philippines, Malaysia, some Caribbean islands, and parts of Mexico, China, and Brazil. A third stratum is made up of large Third World countries such as Brazil, Mexico, Argentina, China, and India, with some industrial potential to join the third technological revolution with local resources. The main danger for these countries is the development of a disarticulation in their economies and societies between integrated and disintegrated sectors to the world economy. The latter would be largely marginalized from the benefits of new development. The major OPEC countries make up another stratum. They have been unable to industrialize, despite heavy capital influxes for several years during the oil boom. This may be explained by a number of factors: being trapped in political games of the superpowers, having corrupt bureaucracies, attempting to develop heavy industries with just as heavy technological dependence at the time that these industries were declining in the world economy. Finally, Castells sees the majority of Third World countries as being condemned to economic obsolescence, unemployment, misery, hunger, illness, and individual violence in their large urban centers. Countries in the latter stratum would be either marginalized from the world economy or would experience a "perverse integration" (Castells and Laserna, 1989) through the production and export of illegal crops.

Finally, I suggest four areas of future research to assess the socioeconomic impact of biotechnology in developing countries. First, we should further clarify the new stratification of countries in the international division of labor, and determine which forms of integration to the world economy are most promising for the majority of the people in terms of the distribution of benefits from development. This would also involve the study of "structural processes of technological innovation," which should combine structural analysis with that of the protagonist actors in the economic dynamic of developing countries. I suggest at least the

following actors for close scrutiny: transnational corporations, governments, local entrepreneurs, and international agencies. What will "reformed capitalism" involve for the changing relationships among these actors and how will they distribute the benefits of development?

Second, we should evaluate the potential of the systems of science and technology in developing countries and their existing links with industry. What is the extent of technology transfer and how could this be further promoted? Where scientific capacity or such links are nonexistent, technological dependency or marginalization are inevitable.

Third, what is the character of legal structures in regard to intellectual and industrial property? Do they promote or hinder the development of a local biotechnology industry?

Fourth, we need an analysis of the various industries that will be affected by products of biotechnology and of the industries or institutions that will be charged with their dissemination. In contrast to the GR, which was promoted mostly by public and semipublic institutions, private industry will probably be the main promoter of biotechnology. Given its unequivocal interest in profit maximization, it is likely that the impact of this new institutional framework will be even more socially polarizing than the case of the GR.

ACKNOWLEDGMENTS

The author was a Professor-Researcher at the University of Guadalajara (Mexico) and Visiting Senior Lecturer at the University of Wisconsin–Madison when he conceived and drafted this essay. He wishes to acknowledge the helpful comments by Martin Kenney, Daniel Kleinman, and three anonymous reviewers for *Sociological Forum*.

REFERENCES

Ahmed, Iftikhar
1988 "The bio-revolution in agriculture: Key to poverty alleviation in the Third World?" International Labour Review 127: 53-72.
1989 "Advanced agricultural biotechnologies: Some empirical findings on their social impact." International Labour Review 128(5): 553-570.

Baumol, William J.
1989 "Is there a U.S. productivity crisis?" Science 243:611-615.

Blumenthal, David, Michael Gluck, Karen Seashore Louis, and David Wise
1986 "Industrial support of university research in biotechnology." Science 231:242-246.

Buttel, Frederick H.
1989a "How epoch making are high technologies? The case of biotechnology." Sociological Forum 4:247-260.
1989b "Social science research on biotechnology and agriculture: A critique." The Rural Sociologist 9:5-15

Buttel, Frederick, Martin Kenney and Jack Kloppenburg
1985 "From Green Revolution to biorevolution: Some observations on the changing technological bases of economic transformation in the Third World." Economic Development and Cultural Change 34:31-51.

Castells, Manuel
1986 "High technology, economic policies and world development." Working Paper, Berkeley Roundtable on the International Economy, University of California, Berkeley.

Castells, Manuel, and Roberto Laserna
1989 "The new dependency: Technological change and socio-economic restructuring in Latin America." Sociological Forum 4:535-560.

Cleaver, Harry
1972 "Contradictions of the Green Revolution." Monthly Review 2:80-111.

Cochrane, Willard
1979 The Development of American Agriculture: A Historical Analysis. Minneapolis, MN: University of Minnesota Press.

Crawford, Mark
1987 "Biotechnology's stock market blues." Science 238:1503-1504.

Florida, Richard and Martin Kenney
1990 The Breakthrough Illusion: Corporate America's Failure to Move From Innovation to Mass Production. New York:Basic Books.

Fröbel, F., J. Henricks, and O. Kreye
1980 The New International Division of Labor. Cambridge: Cambridge University Press.

GAO
1986 "Biotechnology: Agriculture's regulatory system needs clarification." Report to the Chairman, Committee on Science and Technology, USA House of Representatives, GAO/RCED 86-59, March.

Garland, Susan B., John Hoerr, Michelle Galen, and others
1989 "Ouch: The squeeze on your health benefits." Business Week 3134: 110-118.

Genetic Engineering News
1989 "Ernst & Young survey finds healthy industry." Genetic Engineering News 9:11.

Goodman, David, Bernardo Sorj, and J. Wilkinson
1987 From Farming to Biotechnology. Oxford: Basil Blackwell.

Hamilton, Joan O'C., Laura Jereski, and Joseph Weber
1990 "Why Genentech ditched the dream of independence." Business Week 3146:36-37.

Hatsopoulos, George N., Paul R. Krugman, and Laurence H. Summers
1988 "U.S. competitiveness: Beyond the trade deficit." Science 241:299-307.

Hewitt de Alcántara, Cynthia
1978 Modernización de la Agricultura Mexicana. Mexico: Siglo XXI Editores.

Kenney, Martin F.
1986 Biotechnology: The University-Industrial Complex. New Haven, CT: Yale University Press.

Kenney, Martin F., and Barbara Hibino
1987 "Biotechnology in Mexican agricultural research: Development of a research agenda." Paper presented in the meetings of the Rural Sociological Society, in Madison, Wisconsin, August 12-15.

Kleinman, Daniel L. and Jack R. Kloppenburg, Jr.
1988 "Biotechnology and university-industrial relations: Policy issues in research and the ownership of intellectual property at a land grant university." Policy Studies Journal 17:83-96.

Kloppenburg, Jack R., Jr.
1988 First the Seed: The Political Economy of Plant Biotechnology, 1492-2000. New York: Cambridge University Press.

Kloppenburg, Jack R., Jr., Daniel L. Kleinman, and Gerardo Otero
1988 "La biotecnología en Estados Unidos y el Tercer Mundo." Revista Mexicana de Sociología 50:97-120.

Mandel, Ernest
1978 Late Capitalism. London: New Left Books.
1980 Long Waves of Capitalist Development: The Marxist Interpretation. Cambridge and Paris: Cambridge University Press and Editions de la Maison des Sciences de l'Homme.

National Research Council
1989 Alternative Agriculture. Washington, DC: National Academy Press.

Otero, Gerardo

1989a "Commodification of science: Biotechnology in the United States and Mexico." Paper presented in the meetings of the Society for Social Studies of Science, Irvine, CA, November 15-18.

1989b "Ciencia, nuevas tecnologías y universidades." Ciencia y Desarrollo (Mexico City) 25:49-59.

1989c "Industry-university relations and biotechnology in the sugar and dairy industries: Contrasts between Mexico and the United States." World Employment Programme research working paper. Geneva: International Labour Organization.

1990 "Biotechnology, agriculture and the environment." Paper presented at the annual meetings of the Rural Sociological Society, Norfolk, VA, August 7-12.

1991 "Biotechnology and economic restructuring: Toward a new technological paradigm in agriculture?" In Albert Sasson (ed.), Economic and Socio-Cultural Implications of Biotechnology for the Third World, Paris: UNESCO (forthcoming).

Pearse, Andrew

1980 Seeds of Plenty, Seeds of Want: Social and Economic Implications of the Green Revolution. Oxford: Oxford University Press.

Peterson, Thane and Larry Armstrong

1990 "Roche's big buy may set off a shopping frenzy." Business Week 3146:38.

Piore, Michael J. and Charles F. Sabel

1984 The Second Industrial Divide: Possibilities for Prosperity. New York: Basic Books.

Quintero, Rodolfo

1989 "Prospectiva de las Agrobiotecnologías en América Latina y el Caribe." Paper presented in the Seminar on General Perspectives and Impacts of Agri-biotechnologies in Latin America and the Caribbean: Political Implications and Strategies, Paipa, Colombia, August 14-17.

Sklair, Leslie

1989 Assembling for Development: The Maquila Industry in Mexico and the United States. Boston: Unwin Hyman.

Sun, Marjorie

1986 "Will growth hormone swell milk surplus?" Science 233:151.

Young, John A.

1988 "Technology and competitiveness: A key to the economic future of the United States." Science 241:313-316.