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ACCUMULATION OF CAPITAL AND AGRICULTURAL RESEARCH TECHNOLOGY: A BRAZILIAN CASE STUDY

The Ohio State University

Ph.D. 1980

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ACCUMULATION OF CAPITAL AND AGRICULTURAL RESEARCH TECHNOLOGY:
A BRAZILIAN CASE STUDY

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
Ivan Sergio Freire de Sousa, B.S., M.S.

* * * * *

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1980

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To Fatima, my wife, and Flavia, Sergio and Junior, our children, who in their many pleasant and unexpected ways of loving, gave me the happiness and strength to do this task.
Acknowledgments

This dissertation is a product of two different, but related, kinds of involvement. First, was my involvement in Brazil with an excellent team of scientists and technicians in a common task of making a new agricultural research organization work. Second, was my involvement as a student in the graduate program at The Ohio State University. This more recent involvement led me in the Fall of 1979 to a productive experience in the Department of Sociology and Rural Sociology at the University of Wisconsin-Madison. In each of these experiences I have found persons and organizations to whom I am very grateful. What follows is an attempt to acknowledge these persons and organizations, together with their major contributions to the social process of making this dissertation a reality.

For example, without the financial support of EMBRAPA (Brazilian State Corporation for Agricultural Research), to which I am linked as a researcher, this dissertation would remain an unrealized project. I am very grateful to EMBRAPA, and in particular to Eliseu Alves, for giving me the opportunity to work for four consecutive years with the problems of linking theory with a specific research agenda. In Eliseu, I always found more than a sincere friendship. His leadership among those who do agricultural research in Brazil and his solid knowledge of Brazilian agricultural production were a constant source of inspiration during my work in EMBRAPA.
For many reasons the Department of Agricultural Economics and Rural Sociology at The Ohio State University was important to my studies. Two reasons are especially important: (1) its acceptance of my initial application not on the grounds of my control over the English language, but on the grounds of my performance in social theory; and (2) its openness in allowing me to advance my curiosity in a distinctively realist conception of science. I have strong reason to believe that these two contributions, both crucial to my dissertation, cannot be taken for granted. Behind the apparent ease with which my academic needs were accommodated, I always found the support, the struggle and the understanding of William L. Flinn. His actions as Associate Chairman of the department and, as my major adviser, his firm and steady guidance in the Ph.D. program gave me the necessary incentives to work. Even now, with Bill’s new functions as President of the Rural Sociological Society and as Executive Director of the Midwest Universities Consortium for International Activities (MUCIA), he never neglected a thorough examination of my manuscripts.

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offered the best courses on theory that I had ever taken. Initial exposure to Erik Wright's works came in late 1978, from reading *Class, Crisis and the State* and his Ph.D. dissertation, "Class Structure and Income Inequality." Last summer, when facing some crucial problems in the process of doing this study, Erik put aside his work to offer valuable assistance. This and other facts about Erik have left me a clear impression of his intellectual sharpness and deep human qualities. Ron read and made helpful suggestions to preliminary drafts of Chapters 1 and 2. His class analysis seminar gave me important directions to some discussion presented in this study.

I am completely sure, however, that no single person lived this work with me as intensely as my fellow graduate student and best friend, Edward G. Singer. Ed was not only an efficient editor of my writings. With his readings of the basic material related to this dissertation, he shaped my arguments in several ways. For this reason, the basic strategy of analysis and the major ideas developed in this study come equally from both of us. Our friendship began in Fred Buttel's classes on Rural Poverty and Environmental Sociology, and grew increasingly with: our readings on the *Grundrisse*; our interest in theory and methodology; our studies in Madison, Wisconsin; our conversations with Erik Wright; and our never-ending discussions and fights around certain theoretical and methodological issues.
Linda Wright-Romero was another fellow graduate student with whom I have had the privilege of both working and establishing a good friendship. Linda was an important presence in the group that discussed the Grundrisse. She is a sharp student of Althusser and Godelier, and helped to shape my theoretical positions in sociology. Linda read several drafts of this dissertation and not only gave suggestions, but helped with the editing as well.

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* * * * * * * *

In light of the complex structural relation that is defended in this study, a brief summary outline of the different chapters which form the dissertation might prove useful:

vii
Chapter 1 is essentially a statement on the problem of how to view the relationship between society and technology according to what we consider the most pivotal argument: the primacy of the relations of production. Chapter 2 summarizes many diverse efforts in the study of the relationship between society and technology, and from their contributions and shortcomings, attempts were made to lay the groundwork for the study of technology and society from the standpoint of the primacy of the relations of production. Chapters 3 to 5 lay out many of the relevant theoretical and methodological implications for such a study. Methodological issues are confronted first (Chapter 3) in order to clarify the strategy and purpose behind theoretical discussions in Chapters 4 and 5, and the empirical investigation in Chapter 6. Chapter 7 provides a synopsis of the arguments and findings along with suggestions for future research in this field.
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CHAPTER 1

INTRODUCTION

This work aims to systematically link the creation of agricultural research technology to the interest of capital in Brazil. By the creation of agricultural research technology, we mean the process of generating and developing new agricultural technology. By capital we refer to "a definite social production relation, belonging to a definite historical formation of society, which is manifested in a thing and lends this thing a specific social character" (Marx, 1977c:814). Elsewhere, Marx also shows that "capital is not a simple relation, but a process, in whose various moments it is always capital" (Marx, 1973:258). Thus, capital is a social relation that needs to be understood as a process of expansion of these relations, i.e., in motion. Interest of capital refers to the expansion of value and appropriation of surplus value (the difference between total labor expended in production and the value of the labor power used up in production, where labor power is the capacity of workers to produce goods and services). In the process of expansion of value and appropriation of surplus value, there are active elements (social forces) that need to be taken into consideration--such as class, class struggle and the role of the state (discussed in Chapter 4)--when an account of this process is being made. Interest of
capital is not understood here as an autonomous and unilinear process. The underlying interest of capital and the conjuncture of social forces act to set limits rather than externally and totally controlling the production of agricultural research technology. Agricultural research technology (systematically discussed in Chapter 5), as a specific form of intellectual labor, has had in capitalist societies a strong tendency to both legitimize power and to exhibit an organic relation with the political relations of domination.

The link or association analyzed here between the creation of agricultural research technology and the interest of capital appears extremely close to the thesis of the inner logic of capital's self-expansion. This thesis, of which basic elements are found in Marx (1977a: 948-1084)—the "Results of the Immediate Process of Production"—has recently been elaborated in the writings of Braverman (1974), Marglin (1976) and Gorz (1976).

The logic of capital's self-expansion argues that not only science and technology but also labor, ideology and politics are subsumed under its laws. Within this context, then, the economic base almost entirely determines—i.e., subsumes—the character of other elements (social, psychological, political and ideological). However, here the logic of capital's self-expansion is considered as a tendency. This logic shapes or limits (and in this sense it is a tendency) the very field of variation in which a network of elements interact (modifying and being modified) with the process of creation of agricultural research technology.
The so-called "interest" of capital (i.e., the expansion of value and appropriation of surplus value) underlying this logic is itself formed and transformed by the accumulation process (a transformation of things and a transformation of relations) and by the social reproduction of the conditions of production. Sociologically, the concept of interest and its transformation is situated in the very field of practices (class practices), i.e., "in the field of class struggle" (Poulantzas, 1978c:109). Thus, the process of creation of agricultural technology will be understood as having some basic characteristics of a relatively autonomous process, and not as a consequence of capital accumulation per se. Within a social context where different modes of determination play important roles, it will be argued that the forms of accumulation put "limits" on the development of the process of agricultural research technology.

**Capitalist Expansion and the Thesis of the Primacy of the Relations or of the Forces of Production**

The above-mentioned argument stems directly from a particular position taken in the debate over the primacy of the forces of production or the relations of production. Among Marxists there is general agreement that technology plays a crucial role in social development and that there exists an intricate connection between social relations and technological development. However, because the forces and relations are fundamental elements in historical materialism and their contradictory combination expresses the general mechanism of social development (Marx, 1970:19-23), differences in how these two terms are conceptualized and related to one another are critical for an explanation of social change in general and, in particular, for an understanding of the nature and role of technology
in social development. To underline the importance of this connection, it is necessary to have a precise conceptualization of the forces and relations of production and their relationship to one another and the meaning of this debate for an explanation of capitalist societies and specifically for the task at hand. By focusing on the process of creation of agricultural technology, which is an important component of the forces of production (i.e., technology) in agricultural activity, it does not mean any implicit acceptance of the assumptions pertaining to the technological Marxist view of social change, where the forces of production enjoy explanatory primacy over the relations of production.

A general definition of forces of production is offered by Cohen (1978:32):

To qualify as a productive force, a facility must be capable of use by a producing agent in such a way that production occurs (partly) as a result of its use, and it is someone's purpose that the facility so contribute to production. But that someone need not be the immediate producer himself. He could be a non-producer in charge of the process. Thus if a person powers a machine by running on a treadmill, the treadmill is an instrument of production even if the treader is unaware of its effect.

The two basic points in this definition are that (1) a force of production is a facility used to produce, and (2) there is an intentional use of the facility on the part of the producing agent. So the forces of production are formed by the means of production (instruments of production, raw materials, space) and by the labor power (the productive faculties of producing agents: strength, skill, knowledge, inventiveness, etc.) In a broad sense, forces of production are what is used in
production (see Cohen, 1978:41). The two "new" elements which constitute the forces of production are, thus, productive knowledge and labor power.

Relations of production are defined by Cohen (1978:63) as the "relations of effective power over persons and productive forces, not relations of legal ownership." More in accordance with the focus of this work, Poulantzas (1978a:18) presents the technical and social relations of production as "a double relationship which encompasses men's relations to nature in material production," i.e., (1) the relationship between the agents of production and the object and means of labor (the forces of production); and (2) the relations between men and other men, i.e., class relations.

Two aspects in these relations of production are pointed out by Poulantzas (1978a). One is economic ownership; the other is possession. By economic ownership "is meant real economic control of the means of production, i.e., the power to assign the means of production to given uses and so to dispose of the products obtained" (Poulantzas, 1978a:18). By possession "is meant the capacity to put the means of production into operation" (Poulantzas, 1978a:18). The relationship between non-workers (owners) and the means of production is characterized by economic ownership which gives to the owners the real control of the means of production. The relationship between the direct producers (the workers) and the means of production "defines the exploited class in the relations of production" (Poulantzas, 1978a:19). In the capitalist mode of production (CMP), the direct producers are completely dispossessed of their means of labor. The actual possession of these means of labor is taken by the
non-workers. The workers possess only their labor power which they sell. Based on these aspects, the center of production relations is the relations through which exploitation occurs.

To assume the position of the primacy of the forces of production over the relations of production lends itself to the position that the process of creation of agricultural research technology is progressive and autonomous of the capitalist mode of production, a fact that would radically reverse the basic position of this study where the creation of agricultural research technology is treated as a dependent variable. A view of the development of science and technology as progressive and autonomous phenomenon is defended, among others, by authors so different as Kautsky (1971:88-158), Stalin (1977), Trotsky (1972), Shaw (1978), Cohen (1978:134-174) and McMurtry (1978:188-239). The core of the argument is that changes and development in society always begin with changes in the development of the productive forces, and, in the first place, with changes and development of the instruments of production. Productive forces are therefore the most mobile and revolutionary element of production. First the productive forces of society change and develop, and then, depending on these changes and in conformity with them, men's relations of production, their economic relations, change. This, however, does not mean that the relations of production do not influence the development of the productive forces and that the latter are not dependent on the former. While their development is dependent on the development of the productive forces, the relations of production in their turn react upon the development of the productive forces, accelerating or retarding it. In this connection, it should be noted that the relations of production cannot for too long a time lag behind and be in a state of contradiction to the growth of the productive forces, inasmuch as the productive forces can develop in full measure only when the relations of
production correspond to the character, the state of the productive forces and allow full scope for their development (Stalin, 1977:31).

Arguing with this very same logic, Cohen (1978:165) says that

... the course of development of the forces, from lower to higher levels, cannot be disturbed by the economic structure, but the rate at which the course is traversed does depend, in part, on features of the economic structure over which the forces exercise incomplete control. It is not written into the forces how fast they will grow: the character of the economy contributes autonomously to settling that.

To Cohen (1978) the relations of production condition the forces of production in three major aspects, all of which, according to him, qualify instead of negate the thesis of the primacy of the forces of production. These aspects are:

1) the relations of production promote the development of the forces of production, but "relations obtained when and because they promote development" (p. 165);

2) the relations of production help to determine the particular path development takes, and this restricts the independent explanatory power of the forces, to the extent that features of the path which explain features of production relations in turn reflect features of production relations not explained by the productive forces (p. 165); and

3) the relations of production "influence the rate of productivity development" (p. 165).
One of the principal criticisms of the "primacy of the 'forces' thesis" is the absence of any theoretical description of the mechanisms by which a fettering of the forces of production transforms the relations of production. When treating class struggle as largely epiphenomenal, the transformation of the relations of production remains theoretically unexplained by the "primacy of the forces" theorists. It is argued in this dissertation that the major force behind social change is not the level of development of the productive forces, but rather is to be found in the nature of the dominant social relations. If the social relations in production are considered primary, class struggle—as class relations expressed in the field of class practices—performs a fundamental role in social change.

Hence, an argument for the primacy of the relations of production allows for "forces of production" that are qualitatively distinguishable on the basis of a determined set of social relations. It is not enough to say that the development of the "forces of production" in themselves set the stage for a change of social relations because at root these forces—feudal, capitalist or socialist—are embedded and operate within different social contexts. This is not to argue, however, that the productive forces are unchangeable within a given structure of productive relations. Nevertheless, it is the predominant social relations and struggle over the nature of those relations that determine whether the scientific and technological aspects of the productive forces will ensure subordination or egalitarian relations within the social organization of production.
The Nature of Social Reality and Its Relation to the Process of the Creation of Agricultural Technology

As the following chapters show in more detail, the production of agricultural research technology is still insufficiently theorized in sociology, and—exactly because of this lack of systematic scientific investigation—in studying this problem, we are far from having been hindered by the "principle of the drunkard's search" so powerfully explained by Kaplan (1964:11). By searching in "unlighted" areas, this work runs a certain risk of falling short of the breadth of explanation that is demanded but research that goes beyond those immediately apparent or well-researched areas has the promise of expanding explanatory power. Althusser (1977b:30) writes that "progress" in science depends "on what it does not know: its absolute precondition is to focus on this unknown, and to pose it in the rigour of a problem." This unknown is not "its 'residue,' what it leaves out" but "what it contains that is fragile despite its apparently unquestionable 'obviousness,' certain silences in its discourse."

Some students of technology (e.g., Rosenberg, 1977:73-74) have emphasized the point that the creation of a mode of analysis within the Marxist tradition in relation to the study of technology still remains to be undertaken. In spite of the increasingly science-based character of agriculture in modern capitalist social realities, the absence of this mode of analysis persists in the area addressing agriculturally related problems. But that predominant science-based character of agriculture seems to necessitate an analytic approach to the problem of the production of agricultural research technology.
The major focus of this work is not the basic characteristics of a creative scientist or the basic institutional features to stimulate the occurrence of creative and useful knowledge in a research organization. Rather, the questions that we are interested in are (1) whether or not there are structural mechanisms that condition the nature of creative scientific activity, and, if so, (2) what is the nature of those mechanisms, and (3) how these structural mechanisms operate on an actual research organization. In this sense, this study examines the connection between technology and social reality. It is hypothesized that agricultural research cannot be interpreted exclusively as creative activity, nor on the other hand as an isolated economic process. Social and political factors are basic to a satisfactory explanation of the process of creation of new technologies. The scientific production of agricultural research and its connections with the dynamics of social reproduction——i.e., reproduction of the social relations and productive forces (e.g., means of production, reproduction of labor power)——is the basic focus of analysis. An understanding of the nature of any agricultural innovation or invention and the clarification of its role in the process of reproduction of the conditions of production (accumulation) largely depend on the precise identification of social and political factors (reproduction of the social relations).

Historically, i.e., in an actual social context, the capitalist mode of production obtains continuity through reproduction. At the same time that it retains the social relations, it also replaces and transforms things. From the point of view of reproduction, there is, thus,
an intertwining "syndrome" in the production process. It is a production of things and also it is a production and maintenance of social relations. Built in this notion of production/reproduction there are also the notions of structure and determination because in a capitalist society there is an articulated relationship between institutions and the process of production and appropriation of surplus value.

Structure refers to the interrelationship among the concrete social institutions that make up society or, as Godelier (1972:336) says, structure "should not be confused with visible 'social relations' but constitute a level of reality invisible but present behind the visible social relations." A structure does not transform itself. It is transformed as a consequence of social forces. To be more precise, it is transformed as an effect of class practice.

Determination does not mean an external cause which totally controls a subsequent activity, but rather, as stated earlier, a setting of limits in the sense that X exerts pressures on Y, giving some limits to the variability in Y. As Williams (1973:4) states,

Now there is clearly a difference between a process of setting limits and exerting pressures, whether by some external force or by the internal laws of a particular development, and that other process in which a subsequent content is essentially pre-figured, predicted and controlled by a pre-existing external force.

It follows from the Marxist notion of determination that the variation that is allowed in the structural determination of one structure on another does not guarantee functional compatibility between the
structures. There is no necessary coincidence between the forms of variation within limits and their functional compatibility. This non-coincidence is the condition of structural contradiction. The subsequent resolution of non-coincidence (or structural contradiction) does not occur at the level of structures, but rather at the level of class practices. Only class struggle can transform structures and mediate the limits in which a particular outcome is realizable (such as revolutionary change in the economic structure, or a restructuring of the state to make it once more reproductive of capitalist relations—see Wright, 1978:20).

The creation of agricultural technology will be analyzed vis-a-vis this pair of concepts (production/reproduction). Luxemburg (1968:32) observes that

... at all stages of social development, the process of production is based on the continuation of two different, though closely connected, factors, the technical and social conditions—or the precise relationship between man and nature and that between men and men. Reproduction depends to the same degree on both these conditions.

As a scientific activity, the generation of agricultural technology has some characteristics which need to be emphasized from the outset. However, this does not mean that in the literature there is a consensus about these characteristics. The contrary is what really can be found. Scientific activity in general—not only specifically the generation of agricultural technology—has been identified (1) as an ideolotical activity to be placed at the superstructural level (Gramsci, 1948:54-57; 1978:468): (2) as a mental activity distinct from the
material (Bober, 1948:20-22); and (3) as a material activity in the
sense that material is not opposed to mental but to social (Cohen, 1978:
45-47). In this latter sense—as a material activity—the generation
of agricultural technology is a component of the productive forces (what
is used in production). The importance of its investigation is stressed
by Marx (1971:266-267) when he highlights the scientific power (accumu­
lation of the skill and knowledge) as "infinitely more important than
the accumulation."

Our discussion of science hinges on the understanding that science
is not a "thing" or "entity." Science is a distinctive human practice
(refer to Chapter 5 for a detailed discussion on this). It represents
a relatively autonomous site and a condition for economic practice.
The notion of relatively autonomous science accepts that economic prac­
tice in some fundamental way defines the terrain upon which not only
scientific, but other, practices occur. In broad terms, the principle
activity involved in scientific practice is that of penetrating phenome­
nal forms of reality to apprehend the more fundamental and determinant
relations.

As discussed above, the treatment that we give here to science is
not the same as that of Cohen (1978). For us the production of agri­
cultural research technology, as any other social practice in a capi­
talist formation, is part of this intertwining syndrome of production/
reproduction discussed earlier. This practice is (1) a production of
things, (2) a production of social relations, and (3) a production of
ideas about these social relations, i.e., ideology in the sense that
this process of production/reproduction expresses itself in the subjective motives and meanings of the scientists (see, for example, Colletti, 1972; Geras, 1973:284-305; Burawoy, 1978:268).

Our point is that the creation of agricultural technology occurs within a specific capitalist economic form. The linkages between the mental and material process (activity) and a complex and dynamic social form are essential to the comprehension of the nature of the resulting scientific or technological output. Sohn-Rethel (1975:65-101) presents a similar position in his analysis of the relationship between the mode of scientific reasoning and the commodity exchange abstraction. Hodgkin (1976:29-60) as well utilizes a process/product distinction considering both the process of production of science and its product as social (Chapter 2 gives a more thorough discussion of the works of Sohn-Rethel, Hodgkin and others).

To reiterate, the process of creation in agricultural research does not depend only on individual creative abilities; rather to explain it we need to place this process historically within a specific, dynamic and differentiated social reality. The development of agricultural research reflects the character and level of society's development and the social relations within it. Within a particular social reality, the process of creation of agricultural technology has its features and functions within regularities and recurrences that produce certain laws. And the identification and explanations of such laws are basic to understanding the emergence of agricultural technologies.
We have stressed the import of establishing the relation between a given social reality or society and that of scientific and technological practices. The question as well should be posed of what is the concept of society. In any science, the concepts utilized are crucial elements in specifying phenomena. Naturally, depending on the theory-hypothesis-construct level adopted, the content of a concept varies significantly. Several studies, such as Mullins (1973) and Ritzer (1975 and 1977) have presented competing paradigms within sociology in a slightly different manner from that elaborated by Kuhn (1970). In fact, the identity between sociology (basically North American Sociology) and functionalism, which became "officialized" by the end of the 1950s (Davis, 1959), has been extremely problematic in the following decades, even in the United States. The point is that, from those competing perspectives, at least three conceptions of society emerge, i.e., the notion of society as (1) aggregate human behavior (Homans, 1959); (2) a relatively permanent social system (Parsons, 1969); and (3) a social formation (Althusser, 1977:42). This latter notion of society and social reality is assumed throughout this study. More clearly, it uncovers class conflict and class interest, and makes more accessible the identification of diverse political interest. A social formation is a definite social totality, a unit of economic, political, cultural (or ideological) levels and of a dominant mode of production together with other modes or elements (Cutler, Hindess, Hirst and Hussain, 1977:169).

Kelly (1977:24) in a similar way presents the notion of social formation as
a specific historical matrix of modes of production which are composed of discrete and relatively autonomous levels: ideological, political, and economic.

Thus, the notion of society (social formation) that we are using here is that in which "society does not consist of individuals, but expresses the sum of interrelations, the relations within which these individuals stand" (Marx, 1973:265). The difference, for instance, that exists between capitalist and workers is "a difference which exists precisely only from the standpoint of society" (Marx, 1973:265).

Research Focus

This analysis centers on the Brazilian national agricultural research network. In 1972, the Brazilian government created a new organization of research, Empresa Brasileira de Pesquisa Agropecuaria (Brazilian State Corporation for Agricultural Research)-EMBRAPA, to replace an old system judged inappropriate, inefficient, ineffective and sluggish. In this sense, the torpid character of the old system demanded a profound modification in the model of agricultural research itself, toward one more appropriate with the conditions of a country with large limitations on human and financial resources.

EMBRAPA would presumably provide an alternative, tailored to the country's financial and human limitations, and attend to the overriding demands of the non-agricultural sectors of the society at large that in different ways called for more foreign exchange (through a more intense participation of the agricultural exports), cheap food for urban consumers, and raw materials for the growing industrial sector.
Historically EMBRAPA emerged in an environment characterized by political repression (Fernandes, 1975), a high rate of economic growth (Bacha, 1977; Mallan and Bonelli, 1977), and a high level of social inequality (Hoffman, 1971). An analytical foray into that concrete historical moment to manipulate the explanatory categories that are endowed with "a social dynamic which is not immediately observable" (Wright, 1978:11), but that has the essential basis for a sociological explanation, would be crucial to facilitate a more inclusive understanding of the emergence of phenomena such as EMBRAPA. The study of the socio-political conditions and mechanisms for emergence of the organization of EMBRAPA is outside the parameters of the problem defined here. We are not addressing the emergence of a particular organization or its consequent structure, but instead determining the limits imposed by social reality and its relation to the creation of technology within this organization.

The primary interest of this study, then, is placed on a macro level involving the basic elements of a specific social reality. We are not interested in observing the process by which technology is generated at the individual level. Nor are we trying to detect "the abilities that are most characteristic of creative people" (Guilford, 1950: 444) or to explain the process of those individual creative abilities.

It is assumed in this study that the determinants of scientific creation are good proxy variables to help understand the output of creativity in agricultural science. The connections between science and
technology on the one hand, and a specific reality on the other, de-
mystify the almost "socially neutral" character of creativity implicit
in some psychological studies dealing with the theme (Guilford, 1950),
and also make possible a more accurate study of the functions performed
by science and technology within the framework of a particular kind of
production (Aronowitz, 1978:130). Although clarifying some issues, the
psychological, economic and sociological approaches (which are syste-
matically presented and discussed in Chapter 2) have at the same time
neglected both the dominant character of the social relation over the
material relation and the importance of the social relation per se as
an instrument of inducing technological inventions. The subordination
of scientific creation to specific forces within a social reality (e.g.,
Kuhn, 1971; Habermas, 1970; Marcuse, 1965), is seemingly not relevant
in a large number of these studies which form the literature on this
theme. This study intends to explore those neglected connections within
a specific realm of the creative activity (practice): the creation of
agricultural research technology.

The unit of analysis of the study is not the individual or inter-
nal operatives of the organization (EMBRAPA) but the Brazilian accumula-
tion process and the limitations it imposes on agricultural research.
There are two major reasons for the choice of this unit of analysis.
First, to assess this process means to analyze the extent to which the
character of the creation of knowledge is limited by a particular or-
ganizational consensus of how the agricultural process of production
should be carried out. This is important because in a given moment
technology and the production process reflect the economic, political and social pressures present in that specific social reality. EMBRAPA, as a national coordinator and executor of agricultural research in Brazil, mediates the reproduction (nonreproduction) of agricultural technology on the one hand, and the agricultural production process on the other.

Secondly, studies from the growing literature on the sociology of organizations emphasize the relationship between a specific "heterogeneous environment" and an organization from which a responsible behavior is demanded (Baldridge and Burham, 1975). The demands and pressures on an organization usually assume different forms such as the political, social and economic (Farmer and Richman, 1964; Schein, 1965), and they sometimes even modify the goals that are set (Simpson and Gully, 1962).

Our interest on the creation in agricultural research technology has mainly stemmed from work within EMBRAPA, and from the discussion presented by Alves (n.d.)

Alves (n.d.) makes a distinction between a final and a partial product of research. This latter can be represented by the set \( P = (C,D) \) where \( P \) is the partial product of research; \( C \) are physical elements, such as soil, climate, machines, equipment, inputs and physical output; and \( D \) are the abstract elements of knowledge, i.e., knowledge related to soil conservation, work organization, plant and animal characteristics and so on. Given that different groups of farmers exist, several types of
P can be developed \( (P_1, P_2, \ldots, P_n) \). These different \( P \)'s will be modified when something new occurs in \( C, D \) or both.

The final product of research is derived from \( P \) and from a new element, information about the market. This new set is represented by \( S = (\bar{C}, \bar{D}, \bar{M}) \), where \( S \) is the final product of research; \( \bar{C} \) is a quantitative realization of \( D \); \( \bar{D} \) is the necessary knowledge to implement the quantitative realization of \( C \); and \( \bar{M} \) consists basically of the information about both the market and farmer's decision-making process.

Alves' (n.d.) constructions are important in stressing a new direction of agricultural research in Brazil, a direction that was initially elaborated in Hicks (1932) and in Hayami and Ruttan (1971). ¹⁰/

Both sets, \( P \) and \( S \), have the political, economic, and social demands built within them, but Alves (n.d.) is not interested in discussing and developing this point. His concern is in stressing the importance of socio-economic information to the research organization. The viability of an agricultural technology will increase when the socio-economic information about the eventual consumers becomes available to the organization that produces the technology. This is the meaning of the sub-set \( \bar{M} \) within the final product of research \( (S) \). The position in this work is that the mediation of the primary determinants in obtaining \( S \) (the final product of research) is located at the very structural level, and that these structural determinants shape the character and form of variation of the independent variables usually associated with the creation of the final product of agricultural research.
The final product of research (S) actually is a whole set of S—
S₁, S₂, S₃, ..., Sᵢ, ..., Sₙ. Each one of these final products of re-
search (from S₁ to Sₙ) is supposed to be created for the different kind
of producers that form the agricultural setting, from the clearly capi-
talist farmers to subsistence cultivators. A point for fertile inves-
tigation is whether it is possible for a science which is carried out
as a productive force in the interest of capital to also generate knowl-
edge for those producers marginal to or excluded from the capitalist
process or to create productive forces noncompatible with the limits of
capitalist production. In other words, is it possible for S to be
generated—as it presumably is in EMBRAPA—in the service of small and
subsistence farmers? Or are there some sort of "limits" to the produc-
tion of S? And, if there are limits, are the forms of S in the service
of small and subsistence farmers incompatible with those limits? These
are the kinds of questions which this work tries to find some "answers."

Since technology is created to fit in a particular social reality,
the character of the technology as a social product explicitly emerges
in Alves' (n.d.) study. The variable to be considered in research is
now, for him, not only technology, but also the other elements of the
social formation. Thus, following the work of Alves, it is our posi-
tion that only by analyzing the connection and interrelationship between
technology and the social formation can the process by which agricultural
technology is generated be understood. Agricultural research that stres-
ses P as its final product of research is only concerned with uncovering
the laws that govern the development of the means of production and articles of consumption without any consideration to the relationship of these laws to social practice. It is the connection between technology and the social formation which makes the difference between explaining the process of creating agricultural technology and simply describing it. In a particular social formation, scientific technology, the characteristics of the capitalist economy, the structure of social classes and the organization of the political power in the state are intrinsically bound together. Thus, in a sociological explanation, to segment this set of elements is to lose explanatory power. The intent of this study is to maintain these linkages when analyzing the creation of agricultural technology in EMBRAPA.

Stated in a different manner, in any capitalist social formation there is a disjunction between its appearance and its essence. To describe the appearance is not necessarily to touch the reality. This latter is located at the level of essence. Productively applicable knowledge is material in the sense used by Cohen (1978), but its development is not autonomous. Built into this productively applicable knowledge there is a social component that really explains that material presentation. A particular technology at the level of appearance (which is an extremely important level) is a thing (tractor, combine, etc.), but this thing has another level—the level of essence—which reveals the social content embodied in that thing. This "essence" is not to be understood in the sense of an inner essence from which all social
phenomena flow in a mechanistic way. Rather, essence refers to the realm of real determinations that underlie the level of appearance and through which those appearances can be understood more fully.

The formula $P = (C, D)$ hides an important subset that the formula $S = (C, D, M)$ shows in a more explicit way. The function of this work is, thus, to make a more exhaustive analysis of those social mechanisms involved in the creation of a new technology. Bunge (1967:3) pointed out that "scientific research starts with the realization that the available fund of knowledge is insufficient to handle certain problems." The important point to us is that the problem of the interface of social mechanisms with the process of creation of agricultural technologies seems not to have received a satisfactory and systematic treatment in sociology. To clear the air on this issue is a complicated task because --to use an expression of Hodgkin (1976)--"the fog is thick."
FOOTNOTES FROM CHAPTER 1

1/ It should be made clear that in this discussion the expansion of value and appropriation of surplus value is a common underlying interest of the capitalist class. This is not to suggest, however, that this class is homogeneous in its pursuit of this interest. Fractions of the capitalist class do have particular interests over which struggle occurs and they are, as well, subject to different forms of limitations which are discussed in Chapter Three.

2/ Refer to Chapter Three for an explanation on the modes of determination.

3/ "There is a story of a drunkard searching under a street lamp for his house key, which he had dropped some distance away. Asked why he didn't look where he had dropped it, he replied, "it's lighter here!" (Kaplan, 1964:11).

4/ As stated earlier, means of production are formed by the instruments of production, raw materials, land and buildings in which production is undertaken. As such, means of production is a component part of the forces of production, but cannot be equated with it.

5/ The Schumpeterian distinction between innovation and invention is discussed in Chapter Two.

6/ A more detailed account of the nature of structural relations is given in Chapter Three. Structural contradictions (which appear as crisis) are discussed in Chapter Four.

7/ Chapter Five will present and discuss science and technology as distinct (but related) practices.

8/ Guilford (1950:44) says that "in its narrow sense, creativity refers to the abilities that are most characteristic of creative people. Creative abilities determine whether the individual has the power to exhibit creative behavior to a noteworthy degree. Whether or not the individual who has the requisite abilities will actually produce results of a creative nature will depend upon his motivational and temperamental traits ... the psychologist's problem is that of creative personality."
We are drastically simplifying Alves' construction. Our intent here is to point out his basic ideas and to further develop them in this work.

The limits and differences between Hicks (1932) and Hayami and Rut-tan (1971) are presented in Chapter Two.
CHAPTER 2

IN SEARCH OF A TERRAIN ON WHICH TO STUDY THE PROCESS OF CREATING AGRICULTURAL RESEARCH

The terrain for studying the process of creating agricultural research comes basically from three broadly defined approaches: the psychological, the economic and the sociological. The contributions each of these areas serve as building blocks to be fitted together in a coherent way for the formulation of a new task.

The aim of this chapter is to present and to discuss the contributions of each of these approaches to an understanding of the process by which agricultural technology is generated, i.e., to identify factors within a social formation that help to explain the "limits" of technological creation and development in an organization of research such as EMBRAPA. Thus, the intent of Chapter 2 is not to present what is usually called a "literature review." Rather we will examine the main focus of research within the different disciplines and demonstrate that, in spite of being distinct from the major argument of this dissertation, each has an importance of its own and is a necessary element that needs to be added if a more detailed and multidisciplinary understanding of the process of creation of agricultural research technology
is to be made. Here, the "literature review" is the whole dissertation *per se* and not any of its chapters in particular.

Another important point to be made at the outset is that the psychological, economic and sociological approaches to the study of the process of creation in science and technology are neither the only approaches concerned with the theme nor do they form a unified theoretical enterprise. Other disciplines such as anthropology, philosophy and history have contributed significantly to the major topic of study in this dissertation and some of their insights are found among the major disciplinary contributions highlighted in this Chapter.

**The Psychological Approach**

In the field of psychology, the process of creation in science and technology has been studied under the rubric of creativity.\(^1\) However, the more scientific based studies in creativity were not developed until 1950 when, in a presidential address to the American Psychological Association, Guilford (1950), reviewing the concept of creativity, stressed the need for a theoretical and conceptual distinction between intelligence and creativity.\(^2\)

Creativity, while having been intensely researched, has been unable to solve a basic methodological problem, i.e., the criteria for creativity. In other words, psychologists have not agreed upon which element should be considered the central focus in the study of creativity; the **person** (who are creative people), the **product** (what such a creative person does that can be called creative), and the **process** (how a creative person does what he does).
This problem of criteria was one of the issues discussed in three important conferences on the identification of creative scientific talent at the University of Utah (Taylor, 1956, 1958 and 1959). From these meetings came an outline of possible variables and dimensions potentially involved in the criteria of creativity, suggestions for research on the criteria problem and the implications involved in what is to be measured. For example, if the product of creative thinking is being considered, measurements should take into account two elements: kinds (ideas, patents, etc.) and aspects (value, novelty, etc.) In the case of creative individuals, the identification of particular people in regard to their products, eminence, training and educational status; the organizational responsibility and the identification of psychological traits were suggested to be included in a basic research agenda. In terms of process it was suggested that research should be able to identify the productive process involved in the divergent and convergent thinking as well as work on methods utilized by creative people (such as flexibility, perseverance and planning).

Besides the three basic elements (person, product and process) which shape the criterion problem in the psychological studies on creativity, there are others that should be considered in research. Dellas and Gaier (1970) refer to product, process, individual and environmental factors and "press." Welsh (1975) talks about person, product, process and place (where the creative person shows his/her creativity). Whatever element is considered by researchers, there still are methodological problems involved.
Concentrating the analysis of these methodological problems just on the three basic elements, i.e., person, product and process, it can be said that in the case of selecting individuals for the psychological study of creativity the most well-traveled procedures are: (1) generally acknowledged creativity (the individual selected is accepted as creative by almost all people); (2) secondary sources (usually used to develop an initial group and then a second criterion is applied to select those in the initial group); (3) judgment of experts (opinions from people who are experts in their field and considered qualified to make judgments about others); (4) quantity of works produced (particularly novel products); and (5) psychometric approaches (studies of individuals who meet the criterion set up by the psychologist in the laboratory). In this approach the selected subjects may or may not have been manifestly creative.

A major criticism in terms of selecting individuals accepted as creative by almost all people is that usually these studies are limited to a few case studies. Therefore, the probability of generalizations is reduced considerably. With regard to secondary sources such as biographies and encyclopedias, the basic problem is the validity of the information given including the criteria used by writers and/or editors in reporting creative individual's history.⁴ In the case of experts' judgement, there is the probability of the judges over- and under-estimating a person's creativity and using different criteria to classify a creative person. One of the problems with quantity of work produced is the establishment of a "novelty" characteristic. In this situation there
is not the amount *per se* that is important. The point is to establish the extent to which the products that have been produced deviate from the ones already existing. Finally, despite the fact that the psychometric approach is usually considered more "objective," one cannot forget the fact that psychometric definitions are actually psychologists' definitions.

In relation to the creative product, Stein (1963) suggests that the criteria to be used should be the quality of a novel work and its acceptability as tenable or useful by a group at some point in time. Barron (1965) sees a creative product as "something new." For Mackinnon (1965) a creative product is a response or idea that is novel or statistically infrequent. According to Mackinnon (1965), a creative product should serve to solve a problem, to fit in a situation and accomplish some recognizable goal. This involves three basic elements: (1) sustainment of the original insight; (2) its elaboration; and (3) its full development.

In a more recent work, Griffith (1976) defines a creative product as including two elements: uniqueness and usefulness. As the criteria adopted to classify a product as creative is subjected to rapid changes, they lose reliability.

As with the elements of person and product in creativity, the remaining element, creative thinking (or process), also has some methodological problems. Before any reference to these problems is made, it is important to briefly summarize what the literature says about the process itself.
One of the first attempts to systematize the process involved in creative thinking was made by Wallas (1926). According to this author, the creative process has four stages: preparation, incubation, illumination and verification. Torrance (1962:17) explains these four stages, saying that

First, there is the sensing of a need or deficiency, random exploration, and a clarification or "pinning down" of the problem. Then ensues a period of preparation accompanied by reading, discussing, exploring, and formulating many possible solutions, and then critically analysing these solutions for advantages and disadvantages. Out of all this comes the birth of a new idea—a flash of insight, illumination. Finally, there is experimentation to evaluate the most promising solution for eventual selection and perfection of the idea. Such an idea may find embodiment in inventions, scientific theories, improved products or methods, novels, musical compositions, paintings, or new designs.

The period of "incubation" is usually seen as a time when unconscious mental work is predominant (Poincare, 1952). Guilford (1939) classifies this stage as "a period of waiting." The importance of this period is linked to the fact that the time which seems to be a period of no progress is in reality a time for the collected materials to fall into place.

Kris (1952 and 1953), a psychoanalyst, also includes an unconscious phase in his classification of the stages of the process involved in the development of creative ideas. According to him, there are two major phases: inspiration and elaboration. In the initial phase, the creative individual is described as "driven" because he is experiencing an exceptional stage where thoughts and images tend to flow and where
"things appear in his mind of which he never seemed to have known."

The second phase is characterized by labor, concentration and endeavor. Harris (1959) describes the creative process in six steps: realizing the need, gathering information, thinking through, imagining solutions, verification and putting the ideas to work. A different idea of creative thinking is presented by Torrance (1962:16), who defines it as

the process of sensing gaps or disturbing, missing elements; forming ideas or hypotheses concerning them; testing these hypotheses; and communicating the results, possibly modifying and retesting the hypotheses.

A different approach is taken by Rogers (1971:3-4) who defines the creative process as "the emergence in action of a novel relational product, growing out of the uniqueness of the individual on the one hand, and the materials, events, people, or circumstances of his life on the other."

Guilford (1950, 1959, 1965 and 1967) has contributed significantly to the understanding of the nature of the processes involved in creative thinking, particularly with his studies on mental operations. According to Guilford (1950 and 1959) there are about 50 known factors of the intellect, and there may be many more as yet unknown. Some of the factors identified by Guilford (1950 and 1959) are: cognition, memory, convergent thinking, divergent thinking, and evaluation. Two of these cognitive or intellective modes (factors) have been of particular interest to studies on creativity: convergent thinking and divergent thinking. The
first one is essentially a type of conforming thinking (see Guilford, 1950, 1957 and 1959; Thurstone, 1952; Getzels and Jackson, 1958 and 1960). People with convergent thinking retain the known, learn the predetermined and conserve what is. Guilford (1973) says that this type of thinking is the "most frequently encountered in our schools." On the other hand, those with divergent thinking tend to revise the known, explore the undetermined and construct what might be (Wallach and Kogan, 1965 and 1973; Guilford, 1965; Torrance, 1961). It seems that the most objective contribution to the understanding of creativity is the proposed conceptualization of convergent and divergent thinking. In this case, divergent thinking (inquiring, searching around, often leading to unconventional and unexpected answers--Guilford, 1973) would be the process of thinking identified as creative behavior.

The main methodological problem in terms of the creative process or creative thinking is related to its identification and measurement. For example, if the conceptualization of the creative process involves a linear sequence as proposed by Wallas (1926), it is difficult to identify the indicators for each one of these stages, especially those in the "incubation" stage where "unconscious" processes are assumed to be involved. If the focus is on the novel relational product as proposed by Rogers (1971), there is a basic criterion problem related to what can be considered a "novel" product.

Among the different explanations of the creative process, Guilford's conception of divergent thinking has been one of the more developed in terms of measurement. Guilford (1957 and 1959) refers to a number of
sub-processes associated with divergent thinking such as a general sensitivity to problems, associational fluency, expressional fluency, ideational fluency, spontaneous flexibility and adaptive flexibility. These sub-processes have been used as bases for the development of several tests of creativity.

A good summary of the developments of studies about creativity in science is well presented in Taylor and Barron (1963). They collect some of the major papers presented at three national research conferences held, respectively, in August, 1955, August, 1957 and June, 1959 at the University of Utah. From a total of six conferences, five (1955, 1957, 1959, 1961 and 1962) concentrated on identifying creative talent for the sciences. Needless to say, the same problems found in the study of creativity in general are also present in the study of scientific creativity. But it is clear in the papers edited by Taylor and Barron (1963) that the overriding consensus is that psychological aspects of scientific creation are only a portion of the actual process of creation in science. This can be verified, for example, in Guilford's (1963:101) statement:

> to a very large extent certain intellectual abilities should determine what the scientist is able to do. His motivation and his environmental opportunities help to determine what he will do.

Those so-called environmental factors are more closely examined in the economic and sociological approaches.

**The Economic Approach**

Similar to the psychological approach, the economic analysis is not homogeneous nor does it yet have a complete theoretical model of the
research process (Evenson, 1971:163). Economists' contributions to the understanding of creation in research come indirectly from studies on inventions (Hicks, 1932; Usher, 1954; Nelson, 1959 and 1967; Hayami and Ruttan, 1971), resource allocation and the rate of return on agricultural research investment (Griliches, 1957 and 1958; Nelson and Phelps, 1966; Petterson, 1967; Ayer, 1970; Evenson and Kislev, 1975; Boyce and Evenson, 1975). This section will offer a theoretical assessment of the neoclassic approach to scientific production.

From the outset, a focus on "economic growth" is concerned with the level of appearances—that is, only things or events immediately apparent and quantifiable are subject to scientific inquiry. From a realist standpoint, such an analysis, by virtue of its epistemological premises, cannot explain scientific and technological production.5/

A basic concern for economic growth has led technology to be analyzed as: (1) an autonomous factor which occurs independently of socio-economic events (Lewis, 1954; Ranis and Fei, 1961; Jorgenson, 1961); or (2) a dependent factor which responds to economic pressures (Schumpeter, 1949; Hicks, 1932; Hayami and Ruttan, 1971). As pointed out by Ruttan (1959:599), the process by which innovation is generated has not received explicit attention from growth economists and this remains true yet today. Modern exceptions are Hayami and Ruttan (1971), Evenson (1974) and Ruttan (1975), who will be discussed later in this chapter and in Chapter 5.
Schumpeter (1949), who treats technology as a dependent factor, points out a positive correlation between economic fluctuation and technical change. He states that

the economic and the technological combinations, the former concerned with existing needs and means, the latter with the basic idea of the methods, do not coincide. The objective of technological production is indeed determined by the economic system; technology only develops productive methods for goods demanded. Economic reality does not necessarily carry out the methods to their logical conclusion and with technological completeness, but subordinates the execution to economic points of view. The technological ideal, which takes no account of economic conditions, is modified. Economic logic prevails over the technological (Schumpeter, 1949:14-15).

Thus, in the Schumpeterian view of technological development, the driving force of technological innovations is located in the economic realm. Technology is a reflection of economic necessity. Innovation is that which is created under economic pressure, and, after created and allocated in production, produces effects in the economy (Schumpeter, 1939). In his work there is a distinction between innovation and invention.

Innovation is possible without anything we should identify as invention, and invention does not necessarily induce innovation, but produces of itself ... no economically relevant effect at all ... The making of the invention and the carrying out of the corresponding innovation are, economically and sociologically, two entirely different things. They may be, and often have been, performed by the same person; but this is merely a chance coincidence which does not affect the validity of the distinction. Personal aptitudes—primarily intellectual in the case of the inventory, primarily volitional in the case of the businessman who turns the invention into an innovation—and the methods by which the one and the other, belong to different spheres (Schumpeter, 1939:84-86).

In spite of exhaustive work, this distinction has been an empirical approach to the problem (Solo, 1951; Ruttan, 1959; Hayami and Ruttan,
1971). It is very difficult to accept that invention "produces of itself ... no economically relevant effect at all." For Solo (1951:422), invention, as "changes in the level of technological knowledge," is closely related to innovations. Although Schumpeter saw the "possibilities of New Combinations" of inventions with innovations in the institutional pattern of capitalist society, these remained for him more coincidental than relational. If Schumpeter (1939) did not present a theory of innovation, the same cannot be said of Usher (1954), who develops a more complete basis for such a theory (Ruttan, 1959:599).

Usher (1954), a historian, reacting to "the transcendental approach" in psychology and the "mechanistic process theory" of the Chicago School of Sociology, views invention in terms of emergence of "new things." The emergence of these "new things" is a dual process of individual insight and cumulative synthesis.

The process of individual insight involves an "act of skill" (which includes all learned activities), and an "act of insight" (unlearned activities that result in a reorganization of previous knowledge and experience). Individual invention occurs through four stages: "perception of a problem," "setting of the stage," "the act of insight" and the "critical revision" (Usher, 1954:65). Interestingly, these stages of individual invention discussed by Usher (1954) are similar to the sequential stages of the creative process presented by Wallas (1926) and discussed above in the psychological approach.
The process of cumulative synthesis is seen by Usher (1954:68) "as a sequence of strategic inventions which draw together many individual items of novelty as well as many familiar elements." The social process of cumulative synthesis establishes a bridge between Usher's formulations and those of Ogburg (1922) and Giffillan (1935b) discussed later in this paper. Usher, then, sees inventions as a process involving commonly learned elements, individual elements of novelty and the strategic synthesis of these through a cumulative social process.

Hicks (1932), focusing on an analysis of technical change in industry, distinguished two kinds of inventions: "induced" and "autonomous." The former "are the result of a change in the relative prices of the factors" and the latter are "the rest" (Hicks, 1932:125). He showed that a change in the relative prices of the factors of production leads to "biased technological progress"—biased in the sense that the generation of technology economizes the use of the expensive factor(s). Inventions, moreover, can be classified as "labour saving," "neutral" or "capital saving;" that is the initial effects of the invention are, respectively, "to increase, leave unchanged, or diminish the ratio of the marginal product of capital to that of labour" (Hicks, 1932:121). However, Hicks argued that in practice all induced inventions are basically labor-saving but this is not necessarily the case with autonomous inventions.

Criticizing the theory of induced innovations, some have argued that entrepreneurs are interested in reducing total costs and not specific costs such as labour (Salter, 1966:43-44). Fellner (1961) as well presents some objections to the induced innovation model.
More recently, one of the most important contributions to the induced innovations model has been made by Hayami and Ruttan (1971). In their model they argue that: technical change is an endogenous variable in the development process and dependent on economic forces, there are multiple paths to technological development, technology is not neutral in its resource saving characteristics, technical change has the role of facilitating the substitution of one resource for another (Hayami and Ruttan, 1971:43 and 53-61). In short, for Hayami and Ruttan the characteristics of the innovation depend on economic conditions present in a given economy. In this sense, they dynamized Hicks' theory of induced innovations, including in it

the process by which the public sector investment in agricultural research, in the adaptation and diffusion of agricultural technology and in the institutional infrastructure that is supportive of agricultural development, is directed toward releasing the constraints on agricultural production imposed by the factors characterized by a relatively inelastic supply (Hayami and Ruttan, 1971:54).

In other words, Hayami and Ruttan (1971) went beyond Hicks' micro-considerations about firm units adding a macro-economic approach to the theory of induced innovations.

While contributing to the theory of induced innovations, Hayami and Ruttan (1971) have some shortcomings that need to be highlighted when establishing the groundwork for the study of the process of creation of agricultural technology. First, they continue to retail the Schumpeterian assumption that innovation is the basic dynamic and determinant element in the economy. There is a tendency to extrapolate from this that technology and technological change can provide the
solution to the basic problems found in a social formation as a whole.\(^9\) A characteristic of this technological determinism is its emphasis on the supply side such that the solution for agricultural stagnation has been (1) technological development (the creation of new technologies), and (2) the provision of extension services and credit programs (see de Janvry, 1976).

Secondly, their use of the concept of society hides differentiation and contradiction within a social formation so reminiscent of structural-functional analysis in sociology.\(^10\)

A further problem lies with their focus on the market as the key factor in technological development. Their assumption of a free market (i.e., a system of prices that reflects resource scarcity) fails to consider the overwhelming reality of state involvement in the market. Thus, the generalizability of such a model to Brazilian society (not to mention many other cases including the United States) is questionable. In fact, monetarist theorists such as Schultz (1968) and Johnson (1967) call attention to the distorted character of public interventions in the free operation of market forces.\(^11\) Hayami and Ruttan's induced innovation hypothesis cannot account for the effect of other structural forces nor more specifically for the role of public sector investment on technological development.\(^12\) The creation of agricultural research technology for Hayami and Ruttan is a response to market forces (e.g., increasing cost of labor) rather than a response to social forces (e.g., increasing power of labor).\(^13\) Moreover, this focus does not consider
how the market itself is shaped by non-market forces, i.e., what we identified as the conjuncture of social forces which act to set limits within a social formation.

By considering only market forces Hayami and Ruttan (1971) also consider that under capitalism "only those needs expressed through effective demand are socially recognized" (Mandel's Introduction in Marx, 1977:39). De Janvry (1973), in his analysis of the contradiction between "latent" and "actual" demand, considers other kinds of needs than those revealed by effective demand.¹⁴/

A further criticism that can be made of Hayami and Ruttan is their positing of a linear relationship between the creation of new agricultural technologies and the changing relative factor prices common to some branches of the technological determinism. This emphasis on the productive forces, i.e., on the role of agricultural technology as a major stimulant of change, hides rather than reveals the multifaced connections between the creation of technology and social reality.¹⁵/

For example, their "induced institutional change" hypothesis obscures the conditions under which public sector investments occur in agricultural research. If these public investments were motivated by perceived economic return as they suggest, then we would expect to find public allocation of funds to agricultural research technology to be in place with the rate of effective economic return.

The study of economic returns from agricultural research, originating from Marshall's (1930) analysis of economic returns to investment, has been an object of a series of important empirical works from Griliches
(1958) already classical study of the United States to later studies by Ardito-Barletta (1970) in Mexico, Ayer (1970) in Brazil, and Hines (1972) in Peru. \(^{16}\) By relying on Marshall's (1930) concept of economic surplus, the search for a method to estimate the economic benefits of agricultural research turned to the aggregation of consumers' and producers' surpluses. This aggregate measure was then compared with the annual costs of research. \(^{17}\) Again and again these various studies show non-negligible returns to investments in agricultural research programs. Boyce and Evenson (1975), for example, offer findings that show the rate of investment in agricultural research on technology consistently lagging behind the rate of returns.

The concern of this dissertation is not to measure "the rate of return" to agricultural technological investment, but rather to understand the process by which "limits" are placed on the creation of agricultural research technology. It has been argued in this dissertation that it is not the development of the forces of production that primarily leads to change, rather it is the social relations of production. For example, a shortage in agricultural production is not only an exclusive consequence of technological or ecological problems but also and primarily a social one (de Janvry, 1976).

The analyses of the primacy of the forces of production over the relations of production have become increasingly sophisticated in Marxist literature (see Shaw, 1978; Cohen, 1978), and it would be an oversimplification to identify the defense of the primacy of the "forces" with
"vulgar Marxism" as de Janvry (1976:8) does.\textsuperscript{18/} Shaw (1978), who can hardly be classified as a "vulgar Marxist," but as a defendant of the primacy of the "forces" thesis, states:

For Marx, man's social relations, and particularly his production relations—not the productive forces—are the building blocks of the social world and the proper object of social scientific investigation and theory.

The relations of production must be understood on their own level, not as the "effects" of the productive forces to which they correspond ... The degree of advancement of the productive forces explains why a certain set of production relations, a certain mode of production, rather than another, arises (Shaw, 1978:75).

The primacy of the "relations" does not signify a rigid separation between "forces" and "relations" of production; rather, they are assumed to be fundamentally interrelated (see Noble, 1977 and Burawoy, 1978 for additional clarification of this position). It is just this interrelation which is the focus of this dissertation. While the works examined within the economic approach do not necessarily touch on the precise aspect of this problem, they do serve to clarify and at the same time help raise issues that can offer a fuller picture of the process of creation in agricultural research technology.\textsuperscript{19/}

\textbf{The Sociological Approach}

Contributions to the so-called "sociological approach" that are detailed in this section are not exclusive to the field of sociology. In this sense, this section presents, in addition to the traditional sociological contributions of Ogburn (1922) and Ogburn and Nimkoff (1940), some works of mathematicians (Colman, 1971; Hodgkin, 1976), biologists
(Pickvance, 1976) and a whole range of contributions originating in political economy\(^{20/}\) (such as Engels, 1976 and Bukharin, 1971). Thus, the intent of this section remains the same as the others which form part of Chapter 2: to identify a link between science and social reality stemming from these diverse theoretical lines of argument, and to stress the significance of other lines of research which directly or indirectly focus on the process of creation of science and technology.

Ogburn (1922:83) became interested in how far a given cultural base specifically determines a particular invention, assuming a constant level of mental ability. He recognized that this issue \textit{per se} is difficult to resolve because a particular invention is tied together with a whole series of other factors (inventions) and the timing of an emergence of an invention will be a constant problem. In Ogburn's work we can identify two essential but interrelated points. First, Ogburn (1922) disassociates invention from mental ability in the sense that the latter alone explains the former. "Inventions evolve out of the known" or, in other words, it "is the result of an evolutionary process" (Ogburn and Nimkoff, 1940:778 and 780).

It was assumed that changes in the speed of growth of the social heritage were due to the increase of mental ability. This assumption has validity if mental ability is defined as what the mind can do as a result both of learning and inheritance, and not just inheritance alone (Ogburn and Nimkoff, 1940:788).

Secondly, we see the incorporation of an anthropological concept of culture where an ubiquitous cultural entity ties the society together, homogenizing interests. Culture grows as the result of a functional
relation between the existing knowledge and the rate of invention and invention depends upon previous elements (others' inventions) that form part of and are preserved by culture. While the particular image of society excludes class conflict and class interest, inventions are mainly due to "the existing culture" and not only to a specific kind of "necessity" (Ogburn, 1922:83). For Ogburn technological inventions are the "motor" of cultural evolution with accumulation, diffusion and adjustment as secondary factors. Culture, lagging behind the process of invention (cultural lag), continually readjusts to the rate of technological change.

While Ogburn (1922) and Ogburn and Nimkoff (1940) did not construct a theory of inventions, they did make a contribution to it. Basically, their contribution is represented in Figure 2.1, where the arrows show a causal relationship between the three basic variables.

![Figure 2.1. Representation of Ogburn (1922) and Ogburn and Nimkoff (1940) Contribution to a Theory of Invention.](image)

These contributions, as well as those of Ogburn and Thomas (1922), Kroeber (1944) and Barnett (1953), constructed in the same cultural-anthropological framework, not only de-emphasize the individual (as criticized by psychologists—e.g., Stein, 1963), but as well obscure the role of social forces such as class, class structure and class struggle.
Gilfillan (1935a and 1935b) also reflects this tradition of the cultural determination of technology. Gilfillan (1935b), of the Chicago School of thought, tries to construct a concatenated theory of invention. Some of his major points are: invention is partly caused by social factors; invention has wide social effects; patent statistics are questionable measures to mirror invention and unavailable to count major ones; and the "case study" method offers possibilities of a more complete comprehension of the social process of invention.

Gilfillan (1935b) avoided defining invention in a brief fashion. His concept and definition of invention are spread throughout his writings and more specifically in his 38 "social principles" of invention which connect invention with social reality. To Gilfillan (1935b:28), invention is "a combination of several ideas" in the sense that it is a result of a cumulative process which is, above all, social. Invention, then, "is a perpetual accretion of little details," it is "an evolution, rather than a series of creations" (Gilfillan, 1935b:5). Here there is some similarity between his conceptualization of invention and that elaborated by Usher (1954), discussed in the last section of this chapter. To recall briefly, for Usher (1954), strongly influenced by the writings of Ogburn (1922), Ogburn and Nimkoff (1950), and Gilfillan (1935b), "strategic invention" was the cumulative synthesis of many individual inventions.

Gilfillan's (1935b) attempt to construct a concentrated theory can be summarized by Figure 2.2. Each arrow represents the input of an independent variable on the dependent variable invention. The circle
Figure 2.2. Representation of Gilfillan's Concatenated Theory of Invention.
represents the attribute space of the dependent variable, largely defined as "a complex of most diverse elements" (Gilfillan, 1935b:6). Gilfillan's (1935b) shortcomings can be summarized in four basic points: (1) the mechanistic character of his "theory;" (2) the lack of consideration of the creation of technology (invention) within a complex system of social relations; (3) the general laws of social reproduction receive no attention; and (4) the poor formalization of his contribution. But, Gilfillan's (1935b) work has had a positive contribution in that it showed the important connection between invention and social reality.

The same connection is examined by Merton (1949, 1973) in his study of science in general. He establishes an articulation between science and social reality (Merton, 1949:307-316) and further develops his ideas in a theory of the sociology of science (Merton, 1973). Merton's basic concern is with science as an institution: the cultural structure of science. He identifies four institutional imperatives of science: (1) universalism, the claim of impersonal criteria or objectivity; (2) communism, scientific knowledge as a common property; (3) disinterestedness, the accountability of scientists to their colleagues; and (4) organized skepticism, "the suspension of judgment until 'the facts are at hand'" (Merton, 1949:315). These imperatives comprise the ethos of science and play a basic role in his conceptualizations of the "scientific community," the "scientific establishment" and the "invisible college."

The assumptions of these formulations present some drawbacks for a full understanding of the relationship between science and social
reality. While we agree that science is a social institutional structure and there exists a mutual influence between science and its social environment, it is unacceptable in our view that, underlying scientific activity, there is a disinterested search for knowledge. The four sets of institutional imperatives are the foundations of a normative wall which protects the scientific search for "truth." This Mertonian "standard view" of science (see Mulkay, 1979) has "become more and more bound up with the internal workings of the social system of science, and less and less directly interested in the relations that exist between science and the social and political environment in which it takes place" (Sklair, 1973:61).

This can be seen in Merton's discussion of the ethos of science. While recognizing that this ethos of science may not always be consistent with that of the larger society, possibly leading to conflict, if incompatibility occurs, Merton cannot explain the presence of class interest(s) embodied in the scientific work or social reality. Within his functionalist approach, the notion of class—as positions within the social relations of production—is a non-existent concept. In his attempt to relate science (knowledge) and social reality, he developed what can be called a theory of reference group. This theory and its basic conceptual tools of status, role, social integration, social group, culture, mobility, institutions, social structure and socialization are premised on the functional integration of society which enables a disinterested pursuit of scientific knowledge.
A functionalist might state the concern of this dissertation generally as "why it is that most individuals, most of the time, come to 'want' to do what it is that society 'needs' them to do" (Storer, 1966:viii). However, the weakness of such a statement is apparent given the abstract contradiction between the individual and society and in the utilization of the concept society as expressing a homogeneous group of "needs" or interests. Contrasting with the Mertonian functionalist approach, this work argues that the disinterested search for knowledge underlying the scientific activity is only an apparent form of manifestation of that activity. The real determinations of the scientific activity are found in the logic of capital (accumulation) and in the social forces which struggle against the subsumption to capital.

Following the Mertonian tradition, a whole host of studies have been produced (see Ben-David, 1960; Marcson, 1960; Kornhauser, 1962; Abrahamson, 1964; Zuckerman, 1967; Swatez, 1970; Gaston, 1970; Hogstrom, 1971; Clement, 1974). As Storer (1973) states, Merton's investigations have been a "major paradigm" in sociology. However, the identification of the problematic discussed in the "Sociology of Science" as the approach is misleading. To hold to such views is to confuse the functionalist approach and problematic with that of a whole discipline. Nor should the scope of sociological studies of science in the 1970s be understood as a result of a linear development from functionalism. To do so is to ignore the quite different concern of, among others, Braverman (1974), Aronowitz (1978), Noble (1977, 1978), and the Radical
... in the study of science and technology. There are strong theoretical ties between the works of Bukharin (1971) and Hessen (1971), presented at the 1931 London International Congress of the History of Science and Technology and, for example, the recent work of Sohn-Rethel (1975) and Hodgkin (1976) discussed below.

Thus, the social determination of the substance of science is as concrete a concern of study today as the "interactional approach" (concerned with the relationships among individual scientists) and the "institutional approach" (concerned with macro influences on scientific organization and the role of the scientist in society). The research agenda of both the "interactional" and the "institutional" approaches has been strongly structural-functional in character. We now turn to a discussion of those theorists whose explicit concern is the social determination of scientific activity.

Writing in 1878, Engels (1976:45-46) points out at several times that in mathematics

the concepts of number and form have not been derived from any source other than the world of reality. (...) Like all other science, mathematics arose out of the needs of men; from the measurement of land and of the content of vessels, from the computation of time and mechanics.

This connection between science and social reality, is also found in Bukharin (1971):

The idea of the self-sufficient character of science ("science for science's sake") is naive: it confuses the subjective passions of the professional scientist, working in a system of profound division of labor, in conditions of a disjointed society, in which individual social functions are crystallized in a diversity of types, psychologies, passions (as Scholler says:
"Science is a goddess, not a milk cow"], with the objective social role of this kind of activity, as an activity of vast practical importance. The fetishising of science, as of other phenomena of social life, and the deification of the corresponding categories is a perverted theological reflex of a society in which the division of labor has destroyed the visible connection between social function, separating them out in the consciousness of their agents as absolute and sovereign values (Bukharin, 1971:20).

Bukharin's (1971) theory of social transformation not only argues for the social basis of science, but also for the primacy of the forces of production in determining scientific development. Bukharin's technological determinism can be found in the following statement:

The movement of productive forces, the contradiction between them and the historic forms of social labor are, consequently, the cause of the change in these forms, realized through class struggle (to the extent that we are speaking of class societies) and the blowing up of the out-of-date social structure, transformed from "a form of development" to "fetters on development" (Bukharin, 1971:23).

Thus, for Bukharin, the economic structure, formed by the aggregation of the productive forces, has primacy in explaining social change in general and scientific development in particular. Economic contradictions are themselves able to produce social change and revolutionary struggles transforming social relations.

The position that will be developed in this dissertation, contrary to writers such as Bukharin, is that the basis for the existence and reproduction of social classes is the actual form of the process of appropriation of surplus and not economic contradictions in and of themselves. This interpretation of Marx's writings has important consequences for an analysis of the relation between science and technology.
on the one hand and social reality on the other. Science and technology can no longer be viewed as autonomous forces, but rather as "the outcome of the struggle between capital (itself a form of congealed labor under specific historical conditions) and living labor" (Aronowitz, 1978:133). We do not exclude the role of the development of the forces of production in social change, nor its role in setting "limits" to scientific development. What we do argue is that the forces of production do not play the determinant role in social change.

Writers in other fields of research have also utilized the "primacy of the forces" thesis to explain the connections between science and social reality (see Colman, 1971 and Hessen, 1971). Like Engels (1979), Colman (1971:215) defends the thesis that mathematics, as any other science, "is at bottom determined by the development and the position of the forces of production, of technology and economy."

In a more sophisticated and elaborate treatment of the subject, Hessen (1971) reacted against the notion which regards the development of science and technology as the result of personal genius. He argued that Newton's Principia was "in the full sense of the word .. in the centre of the physical and technical problems and interests of his time" (Hessen, 1971:171). To him "great men, no matter how notable their genius, in all spheres formulate and resolve those tasks which have been raised for accomplishment by the historical development of productive forces and production relations" (Hessen, 1971:203).

Bernal (1939) used empirical data to show the involvement of science with large industrial monopolies and the state. More recently,
Pickvance (1976), a biologist, states that the relations of production determine the direction and content of science. "Biology"—he says—"also has a direct productive use, as increasingly the goals of research are determined by industry and the state. Increasingly directly I should say, as they have always been so determined" (Pickvance, 1976:17).

An original and recent contribution to the study of the relation between science and social reality comes from Sohn-Rethel (1975). His principal concern was to reject the norm of timeless-universal logic and, thus, to demonstrate that the logic of scientific thinking originates in social history. His central thesis is that "the forms of the social relations of production are the determinants of the forms of thought" and that "there is a determinate relationship between the mode of scientific reasoning and the commodity exchange abstraction" (Sohn-Rethel, 1975:73). To a great extent, his work is a reaction against the positivist treatment of facts and theories as independent of the social environment. This, he argues, has led to a treatment of science as independent of social values. In Sohn-Rethel's (1975:79) opinion, "the critique of the separation of science from society parallels the critique of the separation of mental from manual labor." Using a dialectical thinking that not only "sees" interaction but also interpenetration between the logical and the historical aspects of mental forms, Sohn-Rethel (1975) suggests a connection between logic and history on the one hand and mental and manual labor on the other that gives meaning to the issues.
He is careful, however, to maintain the distinction between science and ideology. He says:

I do not place science and the conceptual powers of cognition on a level with ideology. Science has objective validity; it accomplishes tasks of social necessity, although it does this with a false consciousness. The traditional and academic philosophies of science are ideology, not science itself. Mathematics is not ideological, even though it is a phenomenon of consciousness (Sohn-Rethel, 1975:74).

Later, he also asserts that:

the production relations of capitalism are represented by the capitalist and presented to the worker as inevitable, inescapable, automatic and natural (law-like) processes. This appearance of determinism and automaticity is not a consequence of the technological nature of the machinery as such; rather, it is part of the ideology of capitalism, which represents particular social relations (and their histories frozen in the form of machines) as natural laws (Sohn-Rethel, 1975:100).

Briefly, Sohn-Rethel (1975) defends the existence of a pure form abstraction which is involved in commodity exchange. This pure form abstraction, determined by human action, is similar to the workshop of all scientific formations. In his theory real abstraction, operated by human social action (such as commodity exchange) is prior to the ideal abstraction operated in thought (see mainly p. 75). In the paper, he aims to show the historical foundations of a basic concept within the Galilean science, the concept of inertial motion. He links Galilean dynamics with the growth ("triumph," is his expression) of capitalism. The rise of modern science is, thus, associated with the rise of modern capitalism. He says:
I have chosen the concept of inertial motion in the Galilean method of modern science as a test case for the historical account of a specific theoretical instrument of science. For this purpose, I shall take the following description of the commodity movement as it forms part of the exchange abstraction, and indeed sums it up: The commodities describe a pure linear movement through abstract—that is, empty, continuous and homogeneous—space and time as abstract substances which thereby suffer no material change and which are capable of none but quantitative differentiation (Sohn-Rethel, 1975:93).

The conclusion is that the form of thinking common to Galilean science and to commodity exchange "plays an important role in maintaining a given set of social and economic relations" (Sohn-Rethel, 1975:97). The dominant structure of production (i.e., the form of the labor process of production) determines the form of social synthesis. To Sohn-Rethel (1975), the dominant structure of production" depends on the stage of development of the productive forces" (see p. 97).

Hodgkin (1976), as well, defends the position that science and social formation are closely linked. His basic argument is that all scientific practice is social and that scientists are social beings not only due to the relationships that they practice outside their work in everyday life, but also "when they are involved in their scientific practice; in fact, this work in some sense determines all the rest" (Hodgkin, 1976:36). Science, in the sense of scientific knowledge, cannot be separated from the society in which it is produced and consumed. More specifically, science exists only in relation to its practice. Both the process of production of science (scientific practice) and its product (scientific knowledge) are social. To Hodgkin (1976) science is
ideological. "I don't mean science is wrong, distorted, or serves ruling-class interests automatically. (...) scientific work, like any other work, takes place within the framework of an 'ideology of practice' ... and this ideology--shared to a greater or lesser extent among a number of scientists--is socially determined, and in its turn determines the choices and orientations for a scientist's practice, so for the kind of knowledge he produces" (Hodgkin, 1976:43). To him it is the demands of a given level of production within a specific social structure which determine science. Thus, in capitalist social formations, science is bourgeois science.

He defends the thesis that in a capitalist social formation a scientific ideology of practice is bourgeois ideology and that "one of its functions is to depict the activity of doing-science-within-capitalism as an acceptable choice for the individual" (Hodgkin, 1976:43). Pointing out "that a large sector of scientific work is now organized directly around and for capital," he examines the influence of capital within mathematics (Hodgkin, 1976:50). He shows that basically after World War II not only a new mathematics, but also a new ideology of mathematical practice emerged. He says:

In the structure of new mathematics--the setting of a precise goal, the drawing up of one or more programmes to achieve it, their evaluation in terms of efficiency, and so on--the knowledge/control polarity seems to be absent. Precisely, the mathematics is centred around the achievement of finite programmes of work. And this says something about the kind of science and scientific ideology which, I think, is best adapted to the present stage of capitalism (Hodgkin, 1976:57).

However, in spite of competition among ideologies of classes or fractions of classes, or for that matter, differences in language, culture, etc.,
there is a certain "rightness" of results which can be expected from science—i.e., science will have a certain "truth" for all classes and in all social formations.

Other contributions to the theme come from Noble (1977). His work is a strong and comprehensive argument against the technological determinism which "most historians of the modern period" have used as "a staple of explanation" (Noble, 1977:xvii-xviii). For Noble (1977), the emergence of modern technology and the rise of corporate capitalism in the United States are two sides of the same process of social production. No separation between "forces" and "relations" of production is assumed. Technology, thus, "is not simply a driving force in human history, it is something in itself human; it is not merely man-made, but made of man" (Noble, 1977: xxi-xxii). A partial but important explanation for the survival of capitalist social relations has to do with the nature of modern engineering as a source of the technological advances. In a historical and sociological analysis, the professional engineers are viewed as the agents of the modern and American corporate capital. The role of the engineer is not only that of being the designer of machinery and processers of production, but also that of managers, educators and social reformers and each of these roles and activities clearly inform the other.

The diverse contributions from the three broad approaches—psychological, economic and sociological—can be more effectively situated on as new terrain if they are treated as building blocks to be fitted together in a more comprehensive manner. This chapter has shown that the
process of creation in science and technology has been approached dif-
ferently from one scientific discipline to another and from one theore-
tical-methodological position to another within a discipline. The psy-
chological approach, in a broad sense minimizes the importance of the
social aspects of the process and concentrates on the study of the
forces within the individual. Thus, the process of creation in science
and technology is approached with the concept of creativity. It was
also seen that the analysis of connections between individual creativity
and social environment is an important issue among psychologists. Indi-
vidual creativity cannot be understood outside of individual-within-so-
ciety unit. The concepts of convergent and divergent thinking (Guilford,
1950, 1959) bring about the importance of this unit.

The economic approach deals with the process of creation in
science and technology mainly through the study of economic growth, where
science and technology are viewed as crucial elements. Two major views
of technology can be identified: as an autonomous factor which occurs
independently of socio-economic events or as a dependent factor which
responds to economic pressures.

The sociological approach has been developed under two major
theoretical traditions: one that has its basic roots in Durkheim, Weber,
Pareto and Parsons, and has been systematized by Merton (1949); the other
is found in Marx and Engels and has in Noble (1977) one of its more re-
cent exponents. Needless to say, the theoretical approach will deter-
mine the research agenda, and, thus, the relevant questions to be raised.
The Mertonian approach has been concerned with the internal workings of
the social system of science (Sklair, 1973). The Marxist approach has been mainly concerned with the relations that exist between science and technology on the one hand and social reality on the other.

By treating the separate and diverse contributions as building blocks, we are not claiming to construct a totally new and original approach via a synthesis of past work. Nor do we intend to engage in "eclecticism" taking the "best" from each approach. Scientific practice is a struggle in which the product, knowledge, always has the quality of incompleteness. Scientific contributions, then, do not come to us as knowledge in its pure or complete form, but rather as incomplete knowledge from which we raise new questions. It is with this in mind, then, that questions are raised within each of the approaches in search of a more adequate framework to understand the role of science and technology in a given social reality.

Psychology, by stressing the individual in scientific development, focused on some relevant issues in terms of intelligence, personality, attitudes and creativity. Failure to theorize "environmental factors," however, created a methodological dilemma in that there was no basis on which to develop the criteria for creativity and a theoretical dilemma by not being able to explain specific forms of creativity. Approaching the problem of science and technology from a different angle, economists stressed economic growth and a mechanistic advance of technology. Although advancing the theorizations of "environmental factors," this second approach falsely separated technology from the social reality in which it emerged. It was, thus, left to the third approach—the
sociological—to situate science and technology squarely within social reality. Here, social reality is not merely "environmental factors," nor mechanical operatives of an ubiquitous market, but rather, a combination of three distinct, yet intrinsically unified elements: economic, political, and ideological. This is the new terrain, or groundwork, at which we have arrived. The task remains to theorize the precise nature of this social reality and situate science and technology within it. The methodological, theoretical and conceptual issues of this new terrain will be discussed in greater detail in later chapters.
FOOTNOTES FROM CHAPTER 2

1/ Stein (1963:217), reacting against the culturalist approach in sociology and anthropology in the study of invention that prevailed in the U.S. during the 1920's and 1930's, says that "in contrast to the method of the sociologist, the psychologist looks to forces within the individual, concentrates on such factors as intelligence, personality, and attitudes, and studies their relationship to creativity."

2/ Guilford (1967:6) points out other factors which were responsible for the increasing research interest in creativity. For example, World War II demanded concentrated effort in research and development, culminating in the atomic bomb. Also, the coming of peace "called for ever-accelerating efforts in a contest of intellects." Another factor was the space age; at this time the stage was set and "ready for the psychologist to play his proper role in trying to fathom the creative person and his creative processes."

3/ Creative thinking is viewed by psychologists as a process, i.e., "the forming of associative elements into new combinations which either meet specified requirements or are in some way useful" (Mednick, 1962:221). Mednick also makes a difference between creative thinking and original thinking. (Creative thinking demands that the answer be useful.) He says, "7.363.474 is quite an original answer to the problem 'How much is 12 + 12?' However, it is only when conditions are such that this answer is useful that we can also call it creative" (Mednick, 1962:221).

4/ Dennis (1956) pointed out the possibility of systematic errors in biographies, histories and lists of best works. Such errors can somewhat favor a man's early work at the expense of his later products.

5/ See Chapter 3 for a more detailed discussion of the diverse methodological implications of the positivist and realist stances in social science.

6/ Solo (1951), refering to Schumpeter (1939), saw this point and made reference to it in his paper.
Salter's (1966:43-44) complete argument is that "the entrepreneur is interested in reducing costs in total, not particular costs such as labour costs or capital costs. When labour costs rise any advance that reduces total cost is welcome, and whether this is achieved by saving labour or capital is irrelevant. There is no reason to assume that attention should be concentrated on labour-saving techniques, unless, because of some inherent characteristic of technology, labour-saving knowledge is easier to acquire than capital-saving knowledge."

Refering to the existence of the adjustment mechanism that directs inventive activities on market economics, Fellner (1961:305) says that "on the conventional static equilibrium assumptions for firms which are very small in relation to the economy, it would be inconsistent to assume the existence of such a mechanism." Furthermore, he emphasizes that "for any given period the superiority or inferiority of an invention to the atomistic firm does not depend on whether the invention is relatively labour-saving or capital-saving" (1961:307).

For instance, to Hayami and Ruttan (1971:285) the "green revolution" "was the result of a direct attack on the basic cause of the widening productivity gap—the inability of the less developed countries to shift rapidly from a natural resource-based agriculture to a science-based agriculture."

One example: "It is unlikely that institutional change will prove viable unless the benefits to society exceed the cost" (Hayami and Ruttan, 1971:61).

The works of Schultz and Johnson are referred to develop countries.

Gold, Lo and Wright (1975b:49-50) have called attention to the fact that "the increasing involvement of the state in the accumulation process has the effect of politicizing the accumulation process itself in the sense that more and more decisions about accumulation are at least partially made in public agencies rather than in private corporate offices. Explicit or implicit political criteria increasingly enter into the organization of production and the allocation of resources in the accumulation process, replacing more purely market criteria."

See, for example, Friedland and Barton (1975), Friedland (1980) and Thomas (1977) for an analysis of how this power struggle induces the creation of new agricultural technologies.
"Latent demand for innovations is that which, when met by supply, leads agricultural development to an optimum consistent with prevailing economic and scientific conditions ... Actual demand, which guides the course of current public sector innovations, is conditioned by government and by socially and politically dominant farm interests, and generally will diverge from latent demand, thus creating lags in the generation of socially optimum innovations" (de Janvry, 1973:411).

Following the classics (Adam Smith and Ricardo), Hayami and Ruttan (1971) do not use the Marxist concept "forces of production;" rather the emphasis is on "productive powers," i.e., productive capacities or productivity. In this sense, it is impossible to find in Hayami and Ruttan (1971) any element, for example, for a theory of the relations between productivity and exploitation or even for the understanding of exploitation as a social process of production (exploitation is here understood as a relation of domination within which people in the dominant position are able to appropriate the surplus labor of those in the subordinate position). Differently, the Marxist concept of "forces of production" goes beyond the concept of productivity or productive capacity. As Therborn (1980:363) states, "its primary reference is rather to the different ways in which productivity is ensured." The dominant concern within the concept of forces of production is with the qualitatively different technical forms of labor and not simply with the quantitative improvement of the productive capacity.

The shortcomings in measuring economic returns in agricultural research are identified by Hertford and Schmitz (1977). A diversified source for the study of resource allocation in agricultural research is Fishel (1971).

Those methods have been subjected to different kinds of criticism (see Boning, 1974; Hertford and Schmitz, 1977).

The expression "vulgar Marxism" needs to be well defined if it is to carry the burden of criticism among the contending theoretical discussions within Marxism. There is nothing "vulgar" about the various competing positions within Marxist theory, only "vulgar Marxists" who betray the very position they set out to defend. Thus, in my opinion there is nothing intrinsically "vulgar" about, for example, the primacy of the productive forces thesis, only "vulgar Marxists" who misrepresent the thesis.
Other studies in the economic sphere, such as Blank and Stigler (1957) and Arrow and Capron (1959) who are interested in supply and demand in scientific manpower, fall distant from the primary objective of this dissertation.

"Political economy studies the social form, which is characteristically mystified and penetrable only by theory" (Cohen, 1978:100).

See Kaplan (1964:298).

"The ethos of science is that affectively toned complex of values and norms which is held to be binding on the man of science" (Merton, 1949:308).

The concept of "scientific community" was later refined by Polanyi (1951), Shils (1954) and Hagstrom (1965). For an elaboration of the concepts "scientific establishment" and "invisible college" see mainly Price (1961, 1963, 1965) and Crane (1969, 1972).

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See, for example, Wright (1978); Bettelheim (1976, 1978a, 1978b); Aronowitz (1978) and Burawoy (1978) for a similar position.
CHAPTER 3

THEORETICAL DISCUSSION I
(Methodology)

This chapter aims to show that scientific research is a tightly integrated activity consisting of, in broad terms, a theoretical phase and a methodological phase. It is crucial for an understanding of the unity of theory and methodology to distinguish our use of the term "phase" from a near synonym "stage." Both terms are useful for delineating any given process, but a process comprised of stages suggests separate blocks of activities related to each other externally. Phases on the other hand, imply an internal relation where the various aspects, dimensions or phases are part of a single and continuous body. This view of scientific research, henceforth to be called realist, will be introduced shortly.

Our central purpose in this chapter is not to present a fullblown critique of a variety of interpretations of the research process nor even to argue in a systematic way for the realist position taken in this dissertation. Fortunately, Bhaskar (1978, 1979) and Keat and Urry (1975) have already provided us with detailed arguments. Our aim is simply to present in a coherent manner some of the more salient concerns that are involved with the realist method of investigation. More specifically, after presenting the structure of a "realist" view of the research
process, definitions of theory and methodology will be advanced and held to be consistent with the realist approach. Following these definitions we will engage in a more detailed discussion on issues pertaining to and forming the realist method of research: the meaning and use of concepts, the notions of causality and determination, the object of a science of society, the explanation/prediction distinction, structuralism, modes of determination and the role of empirical investigation in the research process. In short, the position we take up on each of these issues comprises the rules that govern the effective method and practice of this dissertation. Chapters 4 and 5 will focus on the system of theoretical concepts on which our method and practice of investigation is based.

Bhaskar (1978:145) offers a model (see below) of the research process that includes three distinct approaches: empiricist, idealist and realist. These approaches are seen to correspond to three "phases" of the research process but it is important to note that the phases are themselves transformed as one passes from one approach to another. Thus, it will be shown that only the realist approach is capable of establishing the unity (in the sense of an internal relation) of the distinct phases and bringing us to the point where theoretical activity itself involves a methodological activity (that is, a definitive mode of investigation).

Figure 3.1 shows the classical empiricist stopping at (1), the idealist covering (1) and (2) and the realist passing through three phases. The empiricist interprets the first phase as an empirical regularity from which laws are immediately arrived at through a process
of induction. Although the continual search for a constant conjunction of events may facilitate the objective of prediction, it severely restricts a capacity to explain events (to be discussed below). Moreover, the inductive method of developing a theory provides no means of distinguishing scientific laws from empirical regularities since constant conjunctions may point to either (Keat and Urry, 1975:72).

The existence of an unidentified mechanism which produces observed regularity in phase 1, leads the idealist and realist to interpret phase 1 as a result to be explained and hence, model building is introduced. The realist, nevertheless, differs fundamentally from the idealist in the nature of the produced theory. The idealist, not unlike the empiricist, understands that only what can be observed is real. The resultant
theory can only postulate imaginary constructs that can only be com­
pared and contrasted with the real, while a realist theory, to the con­
trary, appropriates the real in thought. Bhaskar (1978:146) captures
this distinction:

"... whereas for (transcendental) idealism the imagined
mechanism is imaginary, for realism it may be real, and
come to be established as such. What is imagined may
be real; but what is imaginary cannot.

Moreover, at one point in time what is imagined in theory for the
realist (as opposed to what is only imaginary) may, at another point in
time during the research process, come to be real. Thus, the nature of
the theory that postulates real mechanisms provides a built in necessity
for empirical testing (which is phase 3).

At this point, the very sketchy review of the three major tradi­
tions in the scientific research process—empiricist, idealist and
realist—needs some additional comments so as to not mislead the reader.
First, the actual practice of so-called empiricists or idealists does
not reflect in a pure way their respective approaches. Few empiricists
are entirely atheoretical, nor are idealists in practice as purely de­
ductive. Rather, the essential features that are brought out in the
model are held to have a bearing on the extent to which theory can be
linked to observation and vice versa. If theory can be linked to obser­
vation and more broadly to the domain of the real, then theory itself
involves a certain mode of investigation, and, thus, the need for a
methodology. It is on this basis that methodology becomes a matter of
inquiry before we are to the point of "testing" our theory. Second,
the sketchy review serves more to locate realism in its essential
features relative to empiricism and idealism, rather than to offer a
description of each of these positions. Empiricist accounts of the
research process can be found in Hempel (1963) and Kaplan (1964), and
idealist accounts in Weber (1968) and Winch (1959). Again, the purpose
of this chapter is to describe some of the main features of the realist
approach in the research process, and for this we turn first to the
realist conception of theory and methodology.

For the realist, theory provides "causal explanations of observable
phenomena by their description of structures and mechanisms that are
typically beyond observation" (Keat and Urry, 1975:37). Methodology re­
fers to a body of concerns pertaining to the procedures by which the ex­
planatory knowledge produced by theory is constructed. It follows from
the claim that a realist theory is neither the result of inductive nor
deductive procedures—that the scope of methodological concerns expands
from measurement and testing to include and to govern the theoretical
activity, itself.

To make the claim that, for the realist, methodology plays a more
inclusive role in the research process than is the case for the empir­i­
cist, is not to say that for empiricists methodology simply does not
exist until the stage of empirical testing. Rather, rules and proce­
dures do govern the entire empiricist research process, but due to their
positivist orientation with exclusive restriction to the domain of em­
pirical, methodology internal to theoretical activity is largely unprob­
lematic. It is not surprising to see an explosion of methodological
literature addressing concerns of empirical testing (statistical
procedures, measurement, etc.), when for the positivists the sole criteria for the truth or falsity of a theory is obtained through systematic observation and experimentation. What we will attempt to show in the remainder of this chapter is the variety of methodological concerns largely internal to theoretical practice itself but without negating the importance of methodological concerns pertaining to empirical testing.

To focus on methodology internal to theoretical activity is to address the very structure of the realist view of research and the rules which govern it. This is important in terms of the nature of questions that can be posed, how they will be investigated and the extent to which scientific research will describe or explain social reality.

Concept and Concept Formation

Realism (the approach held to best reflect Marx's method for constructing historical materialism) has a distinctive logic of concept formation and of the use of concepts. In this approach, concepts are a way of penetrating an opaque reality which consists of a series of "levels" of determinations. Access to this opaque reality can never be made simply by looking at the observable phenomena. In this sense, concepts can never assume the form of generalizations of the surface phenomena. There is no reason to believe that a general representation of the surface reality identifies the underlying mechanisms which determine that reality. The observable phenomena are located at the level of appearances, while the real determinations are located at the level of
essences (reality). It needs to be stressed at this point that the level of appearances is neither irrelevant nor epiphenomenal. On denouncing appearances as being irrelevant, Wright (1978:11-12) points out:

... the immediately encountered social experience of everyday life is extremely important. People starve at the level of appearances, even if that starvation is produced through a social dynamic which is not immediately observable. The point of the distinction between appearances and underlying reality is not to dismiss appearances, but rather to provide a basis for their explanation.

As for understanding the non-epiphenomenal character of appearances, it is necessary to view the complete social reality (comprised of appearances and essences) as a structural totality of determinations. No level of the social reality plays a non-determining role. Rather, some determinations are argued to be more fundamental than others in the sense that they place different forms of limits on others. The underlying reality constitutes the most fundamental forms of determination; it establishes limits of possible variation of the social reality.

For the moment, assuming appearance/essence is correctly ascribed to the social reality (to be defended below), what is the procedure involved in the formation of concepts and their use? The procedure hinges on the object of reality. Bhaskar (1978) identifies three overlapping domains of reality: real, actual and empirical. The domain of real is formed by the structures and mechanisms, that is, the ways of acting of things. The domain of actual is that of events. The domain of empirical is formed by experiences, where there is no necessary correspondence
with either events or with the underlying structures and mechanisms. Bhaskar's basic argument is that the aim of realist science is to discover and describe the generative mechanisms and structures located in the domain of real. Given that this domain is irreducible to either of the other two, scientific practice aims to reach beyond constant conjunctions of events (since a basic categorical distinction separates the empirical from the real).

The concept becomes the indispensable tool in enabling the discovery and description of the real domain. Given that the domain of real may not be, and frequently is not, directly observable, the concepts held to tap these real mechanisms are likely not to have an empirical referent. For the realist, the absence of an empirical referent to verify a theoretical term is an expected matter, whereas for the positivist it becomes a constant source of confusion and of inconsistencies (see Durkheim, Bunge—in Keat and Urry, 1975). Although positivists admit theoretical (unobservable) terms into their conceptual arsenal, there is no systematic attention given to these concepts, and ultimately explanation falls back on a constant conjunction of events. In the following passage Bhaskar (1978:87) points to what the focus of theoretical activity must be for the realist:

To say that a thing has a power to do something is ... to say that is possesses a structure or is of such a kind that it would do it if the appropriate conditions obtained. It is to enable a claim first and foremost about the thing and, only subsidiarily if at all, about events.

In the above manner, conceptual formation is thus irreducible to either the empirical or actual domains and can be characterized by a
two-fold procedure. This procedure is marked by the establishing of real definitions and by a process of reasoning from apparent effects to prior effects (called retrodiction). These two operations can be seen more accurately as two aspects of the same procedure in that the activity of one presupposes the activity of the other; without real definitions, retrodiction is aimless and without retrodiction real definitions have no depth, and hence cannot penetrate appearances.

Real definitions are fallible attempts to capture the real essences of things. It is a process of breaking down things into their separate and distinct components and analyzing their inner-connections to discern the way things tend to behave separate from (or rather, abstracted from) the actual conditions in which they operate. But the process of untrenching the essences, tendencies or powers of things implies more than a taxonomic account of appearances, if it is to be carried on in conjunction with a process of reasoning from what is empirically evident to prior effects. Sayer (1978) portrays Marx's method of inquiry applied to an analysis of commodities which (already mentioned) can be considered an adequate realist procedure in concept formation and in developing theory. In this portrayal, Marx can be seen to move from phenomenal forms (e.g., commodity) to their prior effects until what appears as a relation between people and things is systematically linked to an underlying social reality. Sayer (1978:53) concludes this account of Marx's practice:

The immediate explanation for why prices diverge from values lies in dislocations in supply and demand consequent upon movements of capital in search of higher
rates of profit. These movements themselves however, are explicable only if *ceteris paribus*, profit varies with the organic composition of capital. This is explained by the theory of surplus value which shows why the surplus value extracted by a capital should be a function of the size of its variable portion alone. But this theory in turn supposes the validity of the law of value, of which it represents an application under conditions specific to a capitalist production.

Chapter 5 of this dissertation represents our own attempt to establish a real definition of technology based on its distinctive components and in search of its pre-conditions. In the attempt to conceptualize technology within the constraints of a theory to be laid out in Chapter 4 (on accumulation and the state), technology is shown to be a particular form of social practice distinguishable from either scientific or ideological practices and, as such, has a distinctive basis for a unity with the structure of social relations.

The concepts emerging from the two-sided realist procedure mentioned above are categorically distinct from the concepts of the other two traditions. That is, the realist conceptual arsenal does not simply posit a different view of reality, but rather differs as well in its structure and use. One of the best distinctions between the concepts for conventionalists (Weber, for example) and those for realists (Marx, for example) is in Erik Wright's work. Wright argues that for Weber the idea of concept emerges as a purely rational construction based on the values and subjective preferences of the theorist. Within this conception of science, concepts are used as yardsticks for comparing "reality" to the ideal type. On the other hand, to Marx (and to the Marxists in general) concepts are rational reconstructions of real
categories/determinations. In other words, concepts are viewed as "microscopes," as an instrument for penetrating structures. This distinction between concepts as yardsticks and as "microscopes" helps to separate two different uses of concepts in science. In the first case (concepts as yardsticks), the concept is an endpoint. In the second case (concepts as microscopes), the concept is the point of departure for science. In a pure empiricist conceptualization of science, a concept is only a way of simplifying a complex reality. To the realists, as argued above, concepts are a way of penetrating an opaque reality.

Causation and the Realist Concept of Determination

We have seen how for the realist a concept is a way of penetrating an opaque reality and appropriating in thought the real object: structure and mechanisms. But in order for explanation to be possible, there must be some notion of causation to express the particular relation among the objects of a social reality. Up to now we have used the realist term determination with only a limited view of its concept. Determination differs from causality in one basic aspect. While the concept of causality involves the notion of prefiguration, prediction and control (bringing with these notions an almost theological account of the world and man—see especially Williams (1973:4)—the concept of determination involves the notion of setting limits. The literature on causality (e.g., Bunge, 1959; Wallace, 1972, 1974; Brand, 1976) shows that the concept of causality varies among the full range of positions within empiricism. In a general sense, causality applies whenever "the
occurrence of one event is reason enough to expect the production of another" (Heise, 1975:11-12). Within a pure Humean tradition, for inferring causality one needs to examine at least three basic points: (1) the contiguity between the presumed cause and effect (high correlation), (2) the temporal precedence (cause has to precede effect in time), and (3) the constant conjunction (cause has to be present whenever the effect is obtained). This radical empiricist view of causality (Russel, 1913; Campbell, 1959) has been strongly criticized (Bhaskar, 1978) and partially transformed (Popper, 1959, 1972). Nevertheless, the identification of reality with experience and the idea of cause as prefiguring its effect is still today an empiricist trademark.

The concept of determination is related to structural causality and not to a conception of reality that is identified only with experience (in this case determination would be an empiricist synonym for causality). To approach determination one needs more than the detection of association between two variables at the level of appearances and investigation into its nature and strength. Fundamentally, one needs to be concerned with the relationship between structures and their manifest effects. The production of agricultural technology is, for example, positively correlated with investment in agricultural sciences (see Evenson, 1978). But it seems that the detection of that association and the observation of its strength and nature are only a part of our understanding of the problem of the process of creation of agricultural research technology. The real determinations of the production of agricultural research technology are located at a different level of reality.
So long as we sustain a distinction between essential relations and their manifest forms (i.e., appearances), Evenson's association and the observation of its strength and nature are only a part of our understanding of the problem of the process of creation of agricultural research technology. Moreover, without grounding these associations in the antecedent conditions for their possibility, such empirical relations can only lead to spurious conclusions. To say that increased investment in agricultural sciences leads to an increase in the production of agricultural technology tells us, at best, what we can expect, while it says virtually nothing about how it is to be explained. What are the conditions under which investment is possible? And, how is the technological level, together with its particular form, to be explained? Measures of association, alone, do not enter into an adequate solution to these questions. At root is the categorical distinction between the real (or essential relations) and their manifest forms. The ways in which essential relations "affect" the ordinary things of the social world must be conceived as situating limits, imposing constraints and setting possibilities for the kinds of action that are possible for a given social form. This kind of determination, a form of causation in the realist sense, entails "effects" that are altogether different from the positivists' notion of causation based on the necessary and/or sufficient condition of a constant conjunction of events, and which postulate effects that only prefigure, predict or control "dependent" variables.
Two additional issues of importance to the realist are uncovered in our discussion on determination: one involves a crucial realist assumption and another the clarification of the notion of a realist explanation.

First, it can be seen that the realist notion of determination (and, for the record, the entire gamut of realist methodology) hinges on the critical assumption that there in fact exist "real mechanisms and structures independent of our thought processes and independent of their manifest forms in the domain of the empirical." To this one must ask why it is important to postulate real determinations that are not directly accessible to observation. Unless this claim receives an adequate defense, a theory that is founded on "real determinations" falls back squarely on the most blatant forms of idealism.

Bhaskar (1979:31-101) considers what the social reality—people and society—must be like in order for sociology to be possible. He identifies two traditional views of the people-society connection, individualism and collectivism which are ascribed to Weber and Durkheim respectively, and argues that neither provides an adequate account of social reality. Individualism incorrectly assumes that social objects are the result of intentional or meaningful human behavior and encourages voluntaristic idealism. Collectivism, on the other hand, assumes that social objects have a "life of their own external to and coercing the individual" (Bhaskar, 1979:40) and encourages "a mechanistic determinism with respect to our understanding of people" (1979:42). The thrust of Bhaskar's argument is that a categorical distinction exists between people
and society so that both render two separate and irreducible aspects of social reality:

The importance of distinguishing categorically between people and societies ... should not be clear ... one can allow ... that purposefulness, intentionality and sometimes self-consciousness characterize human actions but not transformations in the social structure. The conception I am proposing is that people, in their conscious activity, for the most part unconsciously reproduce (and occasionally transform) the structures governing their substantive activities of production. Thus, people do not marry to reproduce the nuclear family or work to sustain the capitalist economy ... when social forms change, the explanation will not normally lie in the desires of agents to change them that way ... I want to distinguish sharply, then, between the genesis of human action, lying in the reasons, intentions, and plans of people, on the one hand, and the structures governing the reproduction and transformation of social activities on the other ... (Bhaskar, 1979:44-45).

The two irreducible aspects argued to sustain social reality call forth two separate (but recognizably complementary) fields of investigation: the structures governing the reproduction and transformation of social activities set the field of investigation for the social sciences while the genesis of human action sets the field of investigation for the psychological sciences. Viewed in this way the field for investigation in a social science, due to its very nature, does not and cannot lay claim to the possibility of deriving individual human actions from social structures and the relations they embody. Bhaskar, likening the relation between the social field and the psychological field to that between the rules of grammar and individual speech acts, sets forth the task of social science:

The rules of grammar impose limits on the speech acts we can perform, but they do not determine our performances ... Looked at in this way, then, one may regard
it as the task of the different social sciences to lay out the structural conditions for various forms of conscious human actions (Bhaskar, 1979:45).

The above argument for the distinction between the social and psychological fields of investigation may demonstrate the necessity for conceiving "determination" in terms of setting limits and imposing constraints on individual and/or collective actions in contrast to the positivists' ascribed meaning for "causality." But we have yet to see how the distinctive nature of "structures" governing the reproduction and transformation of social activities makes not only possible but necessary the appearance/essence distinction, and thereby calls forth a specific object of inquiry (within the broader field of investigation) for the social sciences.

The Object of a Science of Society

It follows from the foregoing discussion that within the determined field of investigation (determined by the argument for its real existence in the world) the object of inquiry for the social sciences cannot be individual actions, beliefs and intentions. Nor can the positivists, in the collectivists' tradition, provide an adequate object of inquiry.

Keat and Urry (1975:83-84) show that Durkheim's criteria for what constitutes social facts are unable to free themselves from psychological factors. Insistence on defining phenomena in terms of readily observable external characteristics, together with establishing a causal criteria of social facts, eliminates the possibility of human intentionality—a clear
affront to the individualist truth that people are the only moving forces in history. Also, "social facts" can only allow for coercive social structures (Bhaskar, 1979:50). For a social science such as sociology to be possible, Durkheim correctly establishes the causal criteria for social facts (where Durkheim's counterpart, anti-naturalists, have failed); but these same social facts cannot sustain a conception of society based on the irreducibility of society and people. Bhaskar (1979:50) then argues that the same causal criteria can establish the reality of social facts on a relational conception of society. It is crucial at this point to note that the relational conception, unlike the collectivist conception, is not reducible to social facts and, therefore, necessitates a non-empirical object of inquiry. Herein lies the possibility for sociology's theoretical autonomy. In short, societies have enduring relations that are rule governing in the sense that they exist and persist independently of human intentions, but these relations do not and cannot uniquely determine individual and group action if we are to sustain the real existence of social transformation and history.

Bhaskar's notion of relational conception is non-empirical in the sense that its existence does not depend on any particular social facts. Indeed, through history social facts can only be manifest forms of social relations that are relatively enduring. "In social life only relations endure" (Bhaskar, 1979:52); therefore, only these relations can explain the manifest forms of social life. In the manner thus described, Bhaskar
(1979:51) locates social forms with respect to the underlying and enduring social relations:

... the relational conception does not ... deny that factories and books are social forms. Nor does it insist that the rules of grammar ... are or must be conceived of as relations. But it maintains that their being social, as distinct from (or rather in addition to) material objects and their consisting in social rules ... depends essentially on ... the relations between people and between such relations and nature ...

It is according to this line of reasoning that in Chapter 5 it is possible to accept technology in its manifest forms as material objects; at the same time, however, it becomes necessary to explain those forms by the underlying social relations of which they essentially depend.

It was mentioned previously that social relations and the social structures they constitute are only relatively enduring. Therefore, theory--whose objects of inquiry are those relatively enduring social relations--is necessarily incomplete. Theory in the social sciences can never fully anticipate new developments in the structure of social relations. For this reason, theory must have an ongoing empirical grounding although at the same time, not collapse the real objects of investigation into the empirical. In this sense, Marx's theory is based on a relational conception of society, but with the further claim of historical materialism--which is, that material production ultimately determines the rest of social life. Historical materialism is essentially a premise to be substantiated in historical investigation. Understood in this way, Marxist theoretical practice implies a definite methodology (that includes realist procedures of concept use and formation), but one that is necessarily open-ended in its product.
To bring this discussion back to the matter of real determinations, it can be said that (1) real determinations exist because they are relatively enduring relations, and these relatively enduring relations must also exist if we are to sustain notions of history and social transformations; and (2) real determinations are defined by the content of those relatively enduring social relations. From (1) we conclude that we are justified in sustaining a distinction between essences and appearances and in maintaining that it points to a real distinction in the social world—which is between essential relations and their manifest forms. From (2) we conclude that real determinations must have an empirical grounding, that they are knowable yet may not be directly observable. Our knowledge of them depends on an adequate blend of intellectual, theoretical and empirical (observational) capacities. This blend has already been shown in this chapter to be best accomplished (in the establishing of real determinations) by realist procedures of real definitions and a process of reasoning from present to antecedent effects. Observational capacities are likewise a necessary element in the realist research approach. Their specific role and their justification will be set forth at the end of this chapter.

Real Determinations and the Concept of Explanation

In the foregoing discussion we have seen how the nature of the field of investigation for the social sciences leads to a specific notion of determination in which the real determinations operate in an open system where there exists a multiplicity of causes and conjunctural moments.
Real determinations can only be understood as setting limits and imposing constraints or opening possibilities but they cannot uniquely determine events. For the realists the form that determination takes is not due to inadequacy of measurement but rather due to the nature of open systems and specifically for social sciences, the nature of the social world. Herein lies the categorical difference between explanation and prediction for the realist.

To predict a phenomenon in traditional social science is to obtain as high a multiple coefficient of determination ($R^2$) as possible. This work involves the selection of variables from an available pool. The selection is made with the intent of obtaining the minimum number of variables necessary to account for the maximum possible variance. To facilitate this process of selection of variables, some methods (such as forward, backward and stepwise solutions) have been developed and incorporated into almost all "canned" programs. From the correlations obtained, general laws are inferred. The constant conjunction of events, which is supposedly reflected in the correlation (assuming no measurement error), becomes the common basis for explanation as well as for prediction.3/

Realists' conception of explanation, on the other hand, seeks to account for the correlations themselves. This kind of explanation involves a "logic of hypothesis formation" that posits "mechanisms and conditions which would, if they existed, respectively explain how and why the phenomena we observe come to assume the forms they do" (Sayer, 1978:114). For realists, to explain a reality scientifically means to
understand the determinations of social life. It means to establish the limits of possible variation of the more surface reality. It means, thus, to understand reality as a totality which is formed by different levels of determination.

When we say that explanation and prediction are fundamentally different notions and that the aim of the realist is explanation, it does not follow that prediction becomes totally invalidated. Rather, prediction retains a certain limited role—one that is hardly unimportant to the research process. To understand this role it is useful to further qualify the role of explanation in view of the realist. The criteria for the rational development and replacement of theories in social science rests with explanation, not prediction. In view of what constitutes a social theory, prediction has no place; due to the absence of decisive test situations, social sciences must work in open systems where no constant conjunction of events prevail, and therefore, no predictive grounds for the establishing of a theory can be sustained. The core of the theory, its basis for validation, can rest on explanatory criteria alone, and explanation in this sense is, as we have just seen, fundamentally different from prediction.

But in the realist research process taken as a whole, explanation has a subsidiary meaning and use that we can call empirical explanation. Empirical explanation is not central to the development of a theory. Rather, empirical explanation belongs to the testing of that theory. We do not have at our disposal the underlying structures and mechanisms or real determinations, but only their effects. The task thus posed for the
testing of a theory is to present those effects in such a way as to show us how it is possible that such underlying mechanisms are indeed in operation. The presentation of those effects by whatever means and techniques is the empirical explanation. Prediction is one of those means and will be discussed together with other testing procedures and concerns in greater detail below.

Real Determination and the Concept of Structure

It has been argued that the basic level of determination is that of structures. However, the concept of structure has at least three different contents in the literature. One of them is essentially empiricist. Structure is seen as a set of persisting social relations (Merton, 1949). Within this orientation, the concept of structure has a basic descriptive content in opposition to an explanatory one. Another conceptualization of structure comes from the historicists (Lukacs, 1976; Weber, 1968). To them, structure (the totality) is the expression of a part: reification and commodification to Lukacs, and bureaucratization and rationalization to Weber. A certain kind of linearity and teleology is implicit in their view of the motion of society (structure). A third conceptualization of structure comes from the structuralists, mainly from Althusser (1971, 1977), Althusser and Balibar (1975), Poulantzas (1978a, 1978b, 1978c), Godelier (1972, 1973, 1977), and others. Here structures cannot be confused with visible social relations. Structure constitutes "a level of reality invisible but present behind the visible social relations." The logic of these social relations, "and the laws of social
practice more generally, depend on the functioning of these hidden structures" (Godelier, 1973:336). In an attempt to push for an explanation of observable social relations from underlying determinations, realists have taken issue with Althusserian structuralism by claiming that it does no more than construct "isomorphic structures of social relations of material, political and ideological production" (Keat and Urry, 1975:137). Their definition is thus: "a structure consists of the system of relationships which underlie and account for the sets of observable social relations and patterns of social consciousness (Keat and Urry, 1975:121).

Modes of Determination

From the idea of structural determination that comes from Marx's writings, a line of work can be identified (Stinchcombe, 1968; Offe, 1974; Godelier, 1972, 1973; Wright, 1978) towards the construction of a systematic atemporal notion of causation—that is, to the development of the modes of determination. Modes of determination are conceptualized as "a series of distinct relationships of determination among the structural categories of Marxist theory and between those categories and the appearances of empirical investigation" (Wright, 1978:15). The notion of modes of determination makes the distinction between independent and dependent variables an empty one. As in system theory, the object of investigation is the complex structure of determination. There is no precedence in time, say, between forms of accumulation and the structure of the state. In this sense, it is not the forms of accumulation which
"cause" the structure of the state. For example, within the totality where accumulation and the state are two of the different elements of the complex structure of determination, they not only simultaneously structure and are structured by each other, but they also structure and are structured by the other elements of the "totality" as well. For this reason we have referred to the modes of determination as being atemporal notions of causation. Wright (1978) systematically develops six different modes of determination which are found to be extremely useful in making explicit the key linkage studied in this dissertation, i.e., that relating the forms of accumulation to the creation of agricultural research technology. These modes of determination are:

1. **Structural limitation**, which is conceptualized as "a pattern of determination in which some social structure establishes limits within which some other structure or process can vary, and establishes probabilities for specific structures or processes that are possible within those limits" (Wright, 1978:16).

2. **Selection**, which "constitutes those social mechanisms that concretely determine ranges of outcomes, or in the extreme case specific outcomes, within a structurally limited range of possibilities. In a sense, selection can be seen as a form of second-order limitation: the setting of limits within limits" (Wright, 1978:17).

3. **Reproduction/non-reproduction**. This more complex mode of determination acts in, for example, preventing a reproduced structure to change in some fundamental ways. As Wright (1978:18-19) explains, this mode of determination "is also a kind of limiting process: it maintains
the reproduced structure within certain limits of variation." He says:

To say that the capitalist state is necessary for the reproduction of capitalist economic relations is not to say that the capitalist state always functions in a perfectly optimal way for the reproduction of those economic relations. It is quite possible for the effects of the state to be far less than optimal, and even under certain circumstances, for it to become non-reproductive. Reproduction/non-reproduction must therefore be understood as a variable relation of determination, not an absolute one (Wright, 1978:19).

4. **Limits of functional compatibility.** This mode of determination designates the limits within which a structure (say, the state) has functional effects or reproductive effects on another structure (say, the class structure). This shows that the reproduction/non-reproduction effect is actually determined by the limits of functional compatibility.

5. **Transformation** represents a direct determination of practices on a particular structure. It involves a conscious objective of transforming a structure. Its intended product is the transformed relations. Wright (1978:21) says that "transformation refers to a mode of determination by which class struggle (practices) directly affects the processes of structural limitation, selection and reproduction/non-reproduction."

Being a direct determination of practices (in the sense that practices act on to transform—or fail to transform—the structure), transformation differs radically from the previous modes of determination—the basic difference being the relation practice to structure and not the relation structure to structure, as in the previous modes of determination. Practice is understood as activities which operate on various kinds of raw
materials (say, relations) in order to generate a particular product (transformed raw material, as for example, transformed relations).

6. Mediation, as transformation, also involves determination of practices on structures. One of the differences is that mediation acts as "contextual effects," i.e., it defines (shapes) the very relationship between two other variables or processes without implying a conscious objective as such. Another difference is that mediation does not only refer to practices mediating the relationship between structures, but also to structures mediating the relationship between structures. For this reason, Wright (1978:23) refers to mediation as "the most complex mode of determination." He also stresses the deep differences between a mediating process and an "intervening" process. While mediating process shapes the very relationship between two other variables, an "intervening" process "is simply a variable which is causally situated between two other variables."

These different modes of determination (which are not yet a complete account of determination) have a major utility in this dissertation: they are the key instruments that make possible our understanding of the relationship between accumulation of capital (a structural category) and the process of creation of agricultural research technology (an empirical event). Agricultural research technology is presented as an "effect" of structural relations. Structural determinations not only shape the course of the process of creation of agricultural research technology, but they put limits on the potentialities of that process to produce innovations as well. It is this concern in linking structures to events which demands the construction of an empirical chapter (Chapter 6) in this work.
The Role of Empirical Testing

The final issue—on empirical testing—will complete our account in this chapter of a realist view of the research process. We have previously mentioned the empirical grounding of the realist account of science. Bhaskar (1975:9) states that the basic principle of a realist philosophy is that "perception gives us access to things and experimental activity access to structures that exist independently of us." At most, the realist principle opens a door to empirical testing, but it is not a sufficient reason for establishing its necessity. Sayer (1978:135-136) offers two reasons as to why establishing independent evidence is necessary for the complete research process.

First, the logic of a realist explanation is not entirely closed. The mechanism or structure that is posited to exist (and logically argued to exist) in order for a phenomena to be possible is not necessarily a unique solution for what is to be explained (even though this form of explanation can drastically narrow the field of competing theories). Thus, on this account there are grounds for the desirability of establishing independent evidence. As we shall see from the second reason, these grounds can never be entirely conclusive for validating a theory.

Second, in their form of explanation, realists posit many unobservable entities that are frequently crucial for the theory as a whole. Such Marxist concepts as value, abstract labor and surplus value are paradigm cases. Their basis for coming into existence in Marx's theory has nothing to do with them being observable phenomena. Rather, their existence depends on the reasoning that they must be real if the phenomena
(that is to be explained) is possible. In the following passage, Sayer (1978:136) shows good reason for submitting such postulations to empirical testing:

... we might ... be suspicious where the sole reason we had for believing in the existence of such unobservables was their capacity to save the phenomena from which the analysis commenced. In this case, critics might opine, the postulated entities and qualities would bear more than a passing resemblance to the equants, epicycles and eccentrics of Ptolemaic astronomy ... One does not have to be a militant positivist to see the desirability of independent evidence here.

Given that many of the terms in explanations of social phenomena do not in any obvious way refer to such phenomena, the establishing of evidence of the real existence of the structures and mechanisms postulated by the terms is clearly problematic. Empiricists have offered two major solutions to the problem of measurement, neither of which is acceptable to realist procedures during the empirical testing phase (see Keat and Urry, 1975: ch. 1 for a discussion of two "correspondence rules" and the technical difficulties they have posed for positivists). The task that is posed for realists on the issue of "measurement" is to seek to indirectly test the hypothetical propositions set forth "by means of evidence of a phenomenal kind" which can be argued to properly substitute for the phenomena to be explained and, "for reasons we can specify before observation, have a bearing on (the) truth or falsity" of the propositions (Sayer, 1978:136). In this manner the two broad fields to be explained—the accumulation process and the creation of agricultural research technology, laid out in Chapters 4 and 5, respectively—are prepared for empirical testing by assigning various indicators for the
accumulation process and for the creation of agricultural research technology.

We defined empirical explanation as the presentation of manifest effects in such a way as to offer inconclusive evidence of the real determinations postulated in the theory. Empirical explanation is applicable only to the testing phase and does not, in a strict sense, explain the phenomena under study. Rather, it is a range of strategies and techniques employed for the purpose of showing (successfully or unsuccessfully) what has already been explained. Thus, empirical explanation consists of technical procedures (for example, quantitative methods) for organizing the data, plus interpretation (to bridge the gap between those effects that represent essential relations and the underlying mechanisms). A specific technical procedure that may be involved in empirical explanation is prediction. Prediction is a deduction from a given law (A) together with a specified set of conditions (B). The predicted outcome is (E).

In this study, (A) is the basic notion that the social relations of production determine the real possibilities and limits for the creation of agricultural research technology. (B) is the manifest conditions to be satisfied if (E) is to occur. Not unlike other social science research, this project is bound to an open system from start to finish; thus, in the absence of decisive test situations, the specification of conditions is severely restricted. In our study, the only conditions specified were those of the accumulation process, which is argued to yield the sharpest indication of the ongoing changes in the structure
of the social relations of production. The logic of our empirical-analytical method can be thus stated: given that the primacy of the social relations of production obtains and specified conditions of accumulation are satisfied, certain specified changes can be expected to occur. But our quantitative treatment in Chapter 6 should not be understood as an attempt to rigorously predict the outcome (a precise type of agricultural technology) where a manifest condition (that is, a prevailing form of accumulation) occurs in a specific form. With the available data, what is being investigated is a tendential relationship between accumulation of capital and the creation of agricultural research technology in Brazil. The data analysis will show indications that the theoretical arguments of Chapters 4 and 5 matter empirically, which is to say that the essential relations concerned with the creation of agricultural research technology are tied together with the mechanisms which reveal them.

As previously mentioned, and to be stressed here, use of prediction as a means of explanation is not to be confused with realist explanation, per se. For the realist, a constant conjunction of events is neither necessary nor sufficient to establish a lawful explanation. It follows from this fundamental realist argument that prediction can play a relatively unimportant role in the research process taken as a whole. Yet its role is a necessary one in as much as social theory is never complete and realist explanation is never closed. Empirical testing is one among several legitimate guides to the description of the ways in which structures and mechanisms tend to act.
FOOTNOTES FROM CHAPTER 3

1/ Among other things, the conventionalists argue: (1) "observations cannot by themselves determine the truth or falsity of theories," (2) "no useful distinction between theory and observation can be maintained," and (3) "there are no universal criteria for choosing rationally between different theoretical frameworks" (Keat and Urry, 1975:5). To the conventionalists, "the data of experience always leave scope for more than one explanatory hypothesis, and which one is to be chosen cannot be determined by experience" (Kolakowski, 1972:159).

2/ Popper (1962: ch. 23) strongly rejects the scientific laws generated by the realists. Based on a distinction between "unconditional historical prophesies" and "scientific predictions" he asserts that Marx's laws of motion of the capitalist mode of production cannot be scientifically tested. For two different criticisms of Popper (1962) see the "Introduction" to volume one of Capital (Marx, 1977a:11-86) written by Ernest Mandel and also Bhaskar (1978).

3/ It should be noted that even empiricists do not identify explanation with prediction. Explanation does require theoretical input (such as an "operator" or intervening variable (see Heise, 1975: ch. 1) where prediction does not. But the empiricist distinction between the two does not keep them, in general, from holding to the view that prediction is symmetrical with explanation.
CHAPTER 4

THEORETICAL DISCUSSION II
(The Basic Conceptual Categories)

The intent of this chapter is to systematically discuss some theoretical issues raised in previous chapters and continue forming the body of the argument for subsequent chapters. In the sense that there is no such thing as Marxism but rather Marxisms, the importance of this chapter is to define our particular theoretical position within Marxism. This will be accomplished through discussion of the basic categories related to the process of creation of agricultural technology.

Marxism is at once a scientific theory, an ideology, a political perspective (political strategy), and an actual political force in the world today. Thus, to highlight Marxism as a scientific theory is not to exhaust its account, but to point out its instruments (theoretical and methodological) of production of a specific kind of knowledge, a scientific one.

Knowledge, per se, is understood as anything that is produced. One of its basic characteristics is that it is a social product. As a social product knowledge is produced by means of antecedent social products. It is with this understanding of knowledge that Bhaskar (1978: 17) refers to knowledge as a produced means of production. In an
Althusserian form, it could be stated that the object of knowledge is the essence of the real object, a fact that distinguishes this object of knowledge from the real object. 1/ Bhaskar (1978) distinguishes two dimensions of the object of knowledge, a transitive and an intransitive dimension. The transitive dimension is that "in which the object is the material cause or antecedently established knowledge which is used to generate the new knowledge" (Bhaskar, 1978:17). The transitive objects of knowledge are the raw materials of science. They include the antecedently established facts and theories, paradigms and models, methods and techniques of inquiry available to a particular scientific school or worker (see Bhaskar, 1978:ch. 1). On the other hand, the intransitive dimension is that "in which the object is the real structure or mechanism that exists and acts quite independently of men and the conditions which allow men access to it" (Bhaskar, 1978:17). These intransitive objects of knowledge are, in general, invariant to our knowledge of them; they are the real things and structures, mechanisms and processes, events and possibilities of the world. They are the intransitive, science-independent, objects of scientific discovery and investigation (see Bhaskar, 1978:ch. 1).

The kind of knowledge that we are refering to—scientific knowledge—is provisory in the precise sense that new understanding about the specific problem that generated that knowledge will later be embodied as the new valid form of knowledge. In this sense, there is no dogma in Marxist scientific production, as there is no dogma in science in general. This scientific process of constant contestation is what makes this work
possible and is what will make possible advancements beyond our own conclusions. Some authors (e.g., Bunge, 1967:4-5), place this fallibilism (the recognition that our knowledge of the world is provisional and uncertain) as one of the basic elements responsible for "scientific progress."

Among others, the Marxist theory of knowledge has at least two basic points: (1) our knowledge of the world is susceptible to modification, and (2) "our knowledge effectually enables us to attain reality, although without even being able to exhaust it" (Geymonat, 1973:188).

In short, Marxism is not a finished theory and it does not claim to be a final product. Marxism, as we are utilizing it here (as a scientific theory), has been built over years. To obtain a growing explanatory power, Marxism needs a constant theoretical and methodological construction where the categories of analysis of a social reality which is hidden behind the level of appearances can be empirically linked to the immediately encountered social experience, giving sense to it, i.e., explaining it. Lenin (1972:211-212) discusses this growth in Marxist theory in the following terms:

We do not regard Marx's theory as something completed and inviolable; on the contrary, we are convinced that it has only laid the foundation stone of the science which socialists must develop in all directions if they wish to keep pace with life.

A cornerstone of Marxist theory has been the logic of capital accumulation. It is through this logic that we can understand the process of social reproduction under capitalism and explain the hidden social
reality. It has been argued that this logic sets limits to the development of agricultural research technology, shaping not only its form and content but also the specific forms of variation of the more direct causal effects. This implies that the process of creation of agricultural research does not develop in a vacuum, but within certain limits and in particular directions set by the "logic" of capitalist accumulation and the contradictions which emerge within this process.

The purpose of the remainder of this chapter is to first give a more thorough presentation of the general logic of capital accumulation. Secondly, to examine different Marxist perspectives on the nature of contradictions and crises which emerge in this process of accumulation. Thirdly, to develop hypotheses relating our understanding of the forms of accumulation and the general limits it imposes on the different probabilities of realizing a certain number of paths in the creation of agricultural research technology. Finally, we will expand our model with a discussion of the structure and role of the state in the accumulation process, hypothesizing its mode of determination on the creation of agricultural research technology.

The Logic of Accumulation

If we are to follow the mandates of a scientific theory of social reality, accumulation cannot be confused with visible relations. The visible aspects of accumulation constitute a determined mode of appearances, i.e., the empirical reality ("domain of actual") which has its determinations in another domain, the "domain of real," to use Bhaskar's
expressions. In this sense, accumulation is not properly a common variable like education, age, race, etc. Accumulation is basically a structural reality as, for example, is the state. A structure cannot be confused with visible relations. At the "domain of actual," visible relations are manifestations of the real determinations located at the "domain of real."

Accumulation consists of a particular combination of elements (i.e., a structure) and the ways in which those elements tend to act (i.e., a process). The basic elements together with their action constitute the real determinations of accumulation as a structural process. As we shall see, accumulation as a structural process is both contradictory and complex. It is a contradictory process in the sense that it develops with crises. It is complex in the sense that in actual social formations it develops in different forms, i.e., there are different forms of accumulation which compete with and temporarily complement each other. The simultaneous existence of different forms of accumulation brings an additional difficulty to the empirical investigation. In our case, for example, each one of these different forms of accumulation signals differently to the generation of agricultural research technology.

Chapter 1 presented the basic argument of this dissertation as being that which relates the creation of agricultural research technology to the mechanisms of social reproduction. At the heart of this process of social reproduction and the mechanisms through which it occurs is the logic of capitalist accumulation. This "logic," as we will see in the
subsequent discussion, reveals not only the expansion of capitalist social relations, but also contradictions and crisis concomitant with their expansion.

The logic of the accumulation process is constructed from the basic components of accumulation rather than from any necessary relation to some exogenous variables. The driving force within the capitalist system is the production of exchange value and surplus value and not the production of use value. Utilizing the terminology of Chapter 1, the "interest of capital," i.e., its driving force, is the expansion of value and the appropriation of surplus value. Use value does not directly embody a social relation; it is an object of utility (Marx, 1977a:131-134) and, as such, is placed outside of the investigation of political economy. Exchange value is a relation between commodities where commodities are exchanged on the basis of the socially necessary labor time used to produce them. When the exchange value is "separated from the commodities and exists alongside them as itself a commodity" it is money (Marx, 1973:145). However, what appears as a relation between things (commodities) is a social relation between the producers of value (labor) and the appropriators of surplus value (capital). Surplus value is the value of the surplus labor appropriated by the capitalist in the process of production, or more technically stated, it is the difference between total value of labor power expended in production and the value of labor power used to reproduce the labor.

Viewed in this way the process of social reproduction implies (1) the reproduction of value (where value is the capacity of workers to
produce goods and services) embodied in constant capital (machines, buildings and raw materials used up in production) and variable capital (value of labor power used to reproduce labor) and (2) the production and reproduction of surplus value. Analyzing the process of accumulation of capital, Marx (1977b:711) states:

The conditions of production are at the same time the conditions of reproduction. No society can go on producing, in other words no society can reproduce, unless it constantly reconverts a part of its products into means of production, or elements of fresh products.

The accumulation of capital means a transformation of things and a transformation in social relations. "Capital accumulation must be understood as the reproduction of capitalist social relations on an ever-expanding scale through the conversion of surplus value into new constant and variable capital" (Wright, 1978:113).

The search for exchange value and surplus value within the "logic" of the capitalist accumulation process defines the interest of capital by the very process \(M - C - M'\) (where \(M\) stands for money, \(C\) stands for commodities and \(M'\) is the increase of the initial \(M\), i.e., \(M' - M = \Delta M\)).

The formulation \(M - C - M'\) has the expansion of value as its objective. This expansion of value is depicted in more detail in the circuit of capital illustrated in Figure 4.1. Figure 4.1 shows money (\(M\)) used to purchase commodities (\(C\)) consisting of labor power (LP) and means of production (MP). These commodities are set to work in production to yield an increase in the value of new commodities and when sold, an increase in money.
where:  
M = money  
C = commodities  
LP = labor power  
MP = means of production  
\cdots P \cdots = production  
C' = increase of C  
M' = increase of M

Figure 4.1. The Circuit of Capital

Three circuits of capital are implicit in the dynamic represented in Figure 4.1. Assuming that M' was reinvested to acquire new labor power and means of production to start a new process, these three circuits of capital could be so defined:  
the money capital circuit (M - M'),  
the productive capital circuit (P - P'),  
and the commodity capital circuit (C' - C'). The non-producing classes appropriate the surplus labor in the form of surplus value. (See Appendix I for a review of simple and extended reproduction and their conversion to the basic structure of social relations.)

Crisis Tendencies of the Accumulation Process

The dynamic of capitalist society is determined by the accumulation of capital, but the development of this accumulation process (expanded reproduction) is not a smooth event. The "logic" of the process reveals impediments and contradictions that bring about crises, the solution of which forge new contradictions and impediments. Competition and class struggle not only make accumulation viable, but within the same field of activity as well forge its impediments.
Beyond the general Marxist orientation to accumulation outlined above, there is no consensus on the exact "logic" one is to follow. Accumulation is a complex process whose structure simultaneously contains several contradictory and counteracting tendencies. In order to obtain a concise picture of accumulation, the task thus becomes one of sorting through the maze of "tendencies" to arrive at the principal processes and elements to be included in a picture of accumulation. The arguments that have emerged to the present day (to be discussed below) together contribute to a broader and deeper view of the complex process known as capitalist accumulation. At least five separate arguments can be identified: (1) the rising organic composition of capital (Mattick, 1969; Yaffe, 1973); (2) the underconsumption thesis (Luxemburg, 1968; Sweezy, 1942; Baran and Sweezy, 1966; Gillman, 1965); (3) the falling rate of exploitation argument (Glyn and Sutcliffe, 1972); (4) the contradictory role of the state in accumulation (O'Connor, 1973; Yaffe, 1973; Offe, 1974); and (5) the "Long Waves" explanation (Mandel, 1975; Wright, 1978). Our intent in the section below is to highlight the major account of each argument and not to make a thorough discussion of those arguments. A more thorough discussion is found, for instance, in Wright (1978: ch. 3).

Each argument carries with it a picture of accumulation, i.e., the principal elements and processes to be included. Together these pictures bring into view a variety of indicators by which to measure accumulation and later (Chapter 6) to show its impact on the creation of agricultural research technology. Needless to say, no "measure(s)" of
accumulation can capture the full complexity of the process. Since we are restricting ourselves to a narrowly defined objective for the strictly quantitative analysis, i.e., to establish the overall impact of accumulation on agricultural research technology, our aim in developing measures from the theoretical arguments will be to draw from each the most fundamental and far reaching tendencies and, subsequently, provide as much as possible the content (empirical indicators) that is consistent with the theoretical arguments. By depicting accumulation in its most fundamental form and direction, we are temporarily putting aside the contradictory forces that are in fact the motor for accumulation. These complexities will be fitted back into the study in the manner of presentation and interpretation of the quantitative analyses.

1) The Rising Organic Composition of Capital

The nature of crises in extended reproduction is explained by proponents of this thesis as an inherent tendency of the capital accumulation process to raise the level of the organic composition of capital, which in turn functions to lower the rate of profit (tendency of the rate of profit to fall).

The organic composition of capital or the value composition of capital (Q) measures the relation of dead (constant capital) to living labor (variable capital plus surplus labor) in production, i.e., \( \frac{C}{V + S} \) (see Mage, 1963). The rate of exploitation or rate of surplus value (3) is the ratio of unpaid to the paid working day, i.e., \( \frac{S}{V} \) or \( \frac{(L - V)}{V} \), where L, as stated above, stands for the total labor expended in production (V + S).
Wright (1978:127) calls attention to an easy and common error; the interpretation of both the rate of exploitation, \( \frac{S}{V} \), "as an expression simply reflecting the state of class struggle" and the organic composition of capital, \( \frac{C}{V+S} \), "as an expression simply reflecting the nature of technology." In different ways, both \( e \) and \( Q \) vary according to both class struggle and technology. Not only does the average level of productivity have a direct impact on the rate of exploitation, but also class struggle has a direct impact on the denominator of the organic composition of capital through the length of the working day and the intensity of work.

Accepting that \( r = \frac{e}{Q(1+e)+1} \) (see the algebraic transformation in Appendix II), this argument of the tendency of the rate of profit to fall when the level of the organic composition of capital rises can also be demonstrated by the partial derivative of the rate of profit \( r \) with respect to the organic composition of capital \( Q \). It is important to stress the point that the above formula for the rate of profit \( r \) already shows that if \( e \) is constant, \( r \) will be the reverse of the direction of \( Q \). The partial derivative of \( r \) with respect to \( Q \) also demonstrates this same tendency of \( r \) to fall with the increase of \( Q \). So, we have:

\[
\frac{\partial r}{\partial Q} = \frac{[Q(1+e)+1] \cdot 0 - e(1+e)}{[Q(1+e)+1]^2} = \frac{-e(1+e)}{[Q(1+e)+1]^2}
\]

(1)

Thus, holding \( e \) constant, when \( Q \) changes (assuming always a positive direction), \( r \) is always negative. The result of a fall in \( r \) is the production of crisis in the general process of accumulation.
The direct cause of the crisis (tendency of the rate of profit to fall) is argued to be due to the non-production of surplus value or, in other words, to the relative scarcity of surplus labor in the production process which "appears as an absolute abundance of commodities in the circulation process" (Mattick, 1969:79). The critical point is that only living labor produces value. In the contradictory logic of the accumulation process, continual technological innovations are made necessary—many of which have the effect of substituting dead for living labor—which, with reduced living labor in the production process, lead to a steady reduction in value of commodities produced. In summary, the theory of the falling rate of profit states that keeping \( \frac{S}{V} \) constant and \( \frac{C}{V} \) rising, the rate of profit \( \left( \frac{S}{C + V} \right) \) will fall.

Some temporary counter tendencies can appear during the process of rising \( Q \), such as the increase in the rate of exploitation of \( e \), but those counter tendencies do not persist in the long run. This can be demonstrated utilizing the result of the algebraic manipulation of the original formula of \( r \) presented in Appendix II and already utilized above. The problem now is to verify what happens to the rate of profit \( r \) when the rate of exploitation \( e \) changes, holding the organic composition of capital \( Q \) constant. The partial derivative of the rate of profit with respect to the rate of exploitation thus assumes this form:

\[
\frac{\partial r}{\partial e} = \frac{[Q(1 + e) + 1] - eQ}{[Q(1 + e) + 1]^2} = \frac{Q + Qe + 1 + eQ}{[Q(1 + e) + 1]^2} = \frac{Q + 1}{[Q(1 + e) + 1]^2}
\]  

(2)
This result shows that, holding Q constant, an increase in r and e assumes the same direction. Wright (1978:131), analyzing the same partial derivative, correctly argues that since Q in the denominator has a higher power than in the numerator, when Q rises, e will change at a higher rate than r.

The overcoming of this kind of crisis occurs through the functioning of several mechanisms such as the elimination of the unproductive capital from the market, the sale of existing constant capital at low prices (below real exchange values), and an increase in the rate of exploitation derived from both the expansion of the relative surplus population and the consequent institutionalization of wages below their value. But the overcoming of a crisis puts accumulation and the organic composition of capital at a higher level, making it more difficult to overcome the subsequent cyclical crises. As Mattick (1969) puts it:

Only a definite amount of new capital, as determined by the amount of physical capital already in existence, will suffice for an accelerated capital expansion. This definite mass of surplus-value refers to total social surplus-value in relation to the total social capital. If this definite mass of surplus-value cannot be produced under the existing conditions, there can be no profitable capital expansion. There may then exist an "abundance" of investable funds which is not large enough to serve the needs of a profitable accumulation. In the real capitalist world it cannot be known, of course, whether the mass of surplus-value is adequate for the purpose of capital expansion. The relationship between the mass of existing capital and the mass of surplus-value needed to assure its reproduction on a larger scale can only be discerned indirectly, through market and price relations which signify either an expanding or contracting economy (Mattick, 1969:69).
In conclusion, the central contradictory force brought into view by those who argue for the tendency of a falling rate of profit is a necessary rise in $Q$ (organic composition of capital), which in turn undermines the basis for surplus value production (living labor) and a crisis occurs. The overcoming of this crisis depends on increasing the exploitation of labor. In turn, this involves, among other things, increasing the productivity of labor. Technical change and struggle at the level of production are thus at the center of this picture of accumulation. Of course, when using indicators of accumulation, the contradictory class relations that underpin and maintain an increasing productivity must be kept in mind. Gross indicators such as the value of the organic composition of capital or the rate of profit, which are more closely tied to the particular theoretical argument, are not available in the data used for this study.

Besides the limits imposed by the available data, there are gaps in the theoretical argument itself. Hodgson (1974) points out the problems of assuming a one-to-one correspondence between technological development and a rising $Q$. The upshot of the counter argument is that if there is no necessary relation between technical change (spurred on in the drive for increasing the productivity of labor) and rising $Q$, then there is no necessity for $Q$ to rise. Despite the gap in the accumulation logic which Hodgson has uncovered, the falling rate of profit argument directly touches many of the most outstanding features of the accumulation process in Brazil since the mid-1960's: increasing productivity and marked technical change. Thus, we accept the argument as it
brings to light one important, if not the most fundamental, dimension of accumulation and yet, following Hodgson's (1974) warning signal, we accept it with reservations and turn to additional interpretations of the nature of the accumulation process.

2) The Underconsumption Thesis

One of the basic positions linking underconsumption to the crisis in capital accumulation is that taken by Luxemburg (1951). The argument centers on making the realization of surplus value the vital condition for capitalist accumulation. There is a "deep and fundamental antagonism between the capacity to consume and the capacity to produce in a capitalist society, a conflict resulting from the very accumulation of capital which periodically bursts out in crises and spurs capital on to a continual extension of the market" (Luxemburg, 1951:347). Within this argument, in a given capitalist society, the growth of demand lags behind the tendency of both the absolute level of surplus value and its rate to rise. When the disproportion between the capacity to produce and the capacity to consume reaches a chronic level, the reduction of investment, unemployment and other features of a capitalist crisis occur.

Sweezy (1942), to whom Luxemburg's formulation "was a clear failure from a logical standpoint," puts the real task of the underconsumption theory as demonstrating "that capitalism has an inherent tendency to expand the capacity to produce consumption goods more rapidly than the demand for consumption goods" (Sweezy, 1942:180). He argues that capitalists' actions lead to a decline in the ratio
rate of growth of consumption  
rate of growth of means of production 

On the other hand, the nature of the production process tends to produce stability in the ratio 
rate of growth in the output of consumption goods  
rate of growth of means of production 

The factor that leads to crises and/or stagnation is the tendency for the rate of growth in consumption to fall behind the rate of growth in the output of consumption goods or, in other words, the tendency for the provision of means of production to exceed the requirements for means of production 

... "underconsumption" and "overproduction" are opposite sides of the same coin. (...) an "underconsumption" crisis may first break out in the sphere of production of means of production, while an "overproduction" crisis may first break out in the sphere of production of consumption goods (Sweezy, 1942:183).

The underconsumptionists' argument that overproduction of surplus value (overproduction of commodities) is the direct result of capitalist accumulation opposes the falling rate of profit argument presented above. Since only living labor produces value, the organic composition theorists argue that the problem is not overproduction of surplus value which is at the root of a crisis, but the absence of it (see Mattick, 1969:79).

In spite of these objections, the logic of the underconsumptionist argument contributes to an understanding of dependent capitalist formations and in particular the situation of Brazil. "Core" countries are seen to resolve their problems of overproduction by expanding their markets through direct investment in production throughout the world.
"Peripheral" countries, however, are in a subordinate position in the world capitalist system and, consequently, the resolution of the crisis of underconsumption is stubbornly problematic. According to the underconsumptionist view, workers appear as consumers to capitalists. Capitalists rely on the low wages of workers for continued accumulation and are continually undercut by the workers' incapacity to purchase the goods produced, thus generating a crisis at the level of circulation. The resultant fall in the rate of profit stymies investments, with the consequence being the development or continued maintenance of a dependency situation with "core" countries. A major symptom of dependency in Brazil is the chronic balance of payments problem partially provoked by the need for massive import substitution in the absence of an internal dynamic of accumulation (which can be ultimately traced back to the contradiction between production and circulation).

The acceptance of the underconsumptionist argument as one dimension of the accumulation process is a reflection of the further complexity of the accumulation process in Brazil, a country marked by dependent development (Cardoso and Faletto, 1979). While the theory of the falling rate of profit explains some important aspects of the dynamics of expansion, the underconsumptionist argument brings into view some aspects of the constraints on this expansion that are particularly salient where dependency relations prevail, as is the case for Brazil in its relation to some "core" countries. One of the most characteristic indicators of the extent to which Brazil is a dependent nation is its foreign debt. The deepening of foreign debt is followed by counter-forces aiming to
overcome the debt relations, i.e., establish the conditions for an internal dynamic of accumulation.

3) The Falling Rate of Exploitation

Crisis in capitalist accumulation does relate to the falling rate of profit, but at a different level from that defended by the organic composition theorists. It is not advances in technology, i.e., the growth of constant capital, that places downward pressure on the ratio \( \frac{S}{C + V} \). The real problem is located in the ratio \( \frac{S}{V} \) as a consequence of class struggle. The increased power of workers in struggle has the practical consequence of putting the growth in wages ahead of productive increases, contributing to a rise in wage bills. Pressured by wage increases, the rate of profit falls, bringing about a decline in investment, productivity and employment. The consequent crisis resolves itself by the growth in the relative surplus population which acts to undermine the working class capacity to struggle (see Glyn and Sutcliffe, 1972).

Severely criticized for de-emphasizing class struggle at the level of production—a neo-Ricardian type position (see Fine and Harris, 1979; Yaffe, 1973; Jessop, 1977)—the falling rate of exploitation theorists also fail to link wage struggles to other aspects of accumulation (Wright, 1978:151). One of the difficulties with theories of the profit squeeze is that they do not distinguish between two situations: one in which profits are squeezed because of rising wage costs, and another in which profits are squeezed by increasing employment of unproductive labor (Wright, 1978:153). The merit of these theorists noted by Wright (1978:
153-154) is their emphasis in the central role of class struggle in the accumulation process.

The profit squeeze argument brings to our understanding of the accumulation process a further dimension which has been important in Brazil. The more characteristic changes in production relations since the mid-1960's have been a sharp increase in the exploitation of labor together with a profit squeeze. These tendencies have accompanied each other partly because of spiralling inflation which has kept wages below cost of living while new conditions are emerging in the agricultural sector. It will be argued in Chapter 6 that the penetration of capitalist relations into agriculture generates its own impediments to accumulation by steadily undermining an agricultural subsistence sector which has in the past crucially functioned to provide cheap food to urban workers and hence, to promote capitalist accumulation (by holding down labor costs) in the urban sector.

4) The Contradictory Role of the State in Accumulation

For O'Connor (1973), the state's activity is not simply an external response to the process of accumulation; rather, the activity of the state is intrinsically bound up with that process. In this manner, the state is seen to not only protect the conditions for accumulation, but it also actively participates in the creation of those conditions. The contradictory role of the state is the result of an attempt by the capitalist state to fulfill two essential but contradictory functions, accumulation and legitimation. O'Connor (1973:64-96) argues that in fulfilling the accumulation function, the state creates the conditions
of profitability for capital accumulation, and in performing the legiti-
timation function, concentrates on creating conditions for the peaceful
reproduction of the entire class structure.

The focus of O'Connor's discussion is the existence of a tendency
for the government expenditures to outpace revenue. Two theses are
presented: (1) "that the growth of the state sector and state spending
is functioning increasingly as the basis for the growth of the monopoly
sector and total production" and (2) "that the accumulation of social
capital and social expenses is a contradictory process which creates
tendencies toward economic, social and political crises" (1973:8-9).

The basic contradiction responsible for these crises is the socializa-
tion of capital costs and private appropriation of the social surplus.
This contradiction induces the fiscal crisis. State power thus is pri-
ately appropriated for particularistic ends, which forces the legitima-
tion function to convert political interests into economic demands.

Some important points of distinction can be drawn between the
Brazilian state and the state analyzed by O'Connor. It seems that
Brazilian state activity cannot be considered either essentially as un-
productive (i.e., does not contribute to the production of value and
surplus value), as implicit in both organic composition and undercon-
sumptionist theories, not only as an indirect contributor to the pro-
duction of surplus value (as is the case of the American state analyzed
by O'Connor). Alavi (1972), for example, has called attention to the
relatively autonomous economic role of the dependent capitalist state.
This same observation is made by Ziemann and Lanzendorfer (1977), who
refer to the development in the periphery of the international capitalist system as "the intervention of State in permanence." In fact, Brazil has an important presence as a direct producer of surplus value in Department I of the economy. On the other hand, as capital accumulation and economic growth are tied together with the growth of the productive forces, Brazilian state investment in research (basically in agricultural research) has undergone a considerable increase (see Chapter 6). This participation of the Brazilian state in research seems to follow O'Connor's thesis in linking the expansion of the state to the expansion of the private sector of the economy (basically the monopoly sector) within which "are the 'engine' of capital accumulation and economic growth" (1973:23).

Some problems have been pointed out in O'Connor's arguments. Mosley (1978:38-39), for instance, questions whether the distinction between the monopoly and competitive sector--essential to O'Connor's argument--sufficiently corresponds to structures of the real world. Important variations occur within each of the two sectors. For instance, within the monopoly sector not only does the nature of the demand for products vary, but the capital intensity and the reliance on high technology vary as well. Mosley (1978:43-44) also questions "whether the current difficulties in state finances are a special phenomenon, a structural crisis in the fiscal system of the capitalist state."

Within the perspective of this work, O'Connor's contributions are no doubt significant. Not only does he highlight the important role
played by the state in the economy as a whole, he as well points out
the increasing involvement of the state in the capital accumulation
process to protect and actively participate in the creation of the con­
ditions of its reproduction. This dialectical link between accumula­
tion and the state will be explored in our discussion of theories of
the state and its relation to the process of creation of agricultural
research technology.

5) "Long Waves" Explanation

The theory of "long waves" developed by Mandel (1975) views the
accumulation process as receiving different immediate obstacles in dif­
ferent stages of development. There is, however, in Mandel (1975) the
idea that the basic constraint on accumulation is the tendency for the
organic composition of capital to rise, which brings about all the
structural limitations discussed above in item 1. But one of the basic
points in Mandel (1975) is the position that capitalist development is
a process with phases, each phase with its own determination and speci­
fic characteristics. There is no necessity for the determinants of one
phase of capitalist development to persist into the next. Mandel's
"solution" to the problem of "long waves" was in relating

the diverse combinations of factors that may influence the
rate of profit (such as a radical fall in the cost of raw
materials; a sudden expansion of the world market or of
new fields for investment for capital; a rapid increase or
decline in the rate of surplus-value; wars and revolutions)
to the inner logic of the process of long-term accumulation
and valorization of capital, based upon spurts of radical
renewal or reproduction of fundamental productive technol­
ogy (Mandel, 1975:145).
Mandel (1975) fails to clarify (1) the influence of social economic factors on technology, (2) how far he "believes a 'technological revolution' is an ongoing process of discovery," and (3) how far a technological revolution "rests upon the exploitation of discoveries which had already been made when the 'revolution' began" (Rowthorn, 1976:63).

Wright's (1978) position differs from that of Mandel's (1975) in several basic points. To Wright (1978), for instance, the social organization of production, the forms of competition and class struggle can be as decisive as technology (in a broad sense, the forces of production) in characterizing different periods of accumulation. In studying the social transformation of capitalist crisis, Wright (1978) is interested in understanding "the social processes which tend to push the forms of accumulation outside those limits of functional compatibility, thus generating structural crises within the accumulation process" (p. 165). He argues that the articulation of the forces/relations of production create structural limits on the forms of accumulation in a given period and determine "the extent to which a given form of accumulation will be reproductive or non-reproductive of those forces/relations of production (i.e., they establish limits of functional compatibility)" (pp. 164-165).

Wright's (1978) model of determination of the accumulation process reproduced in Figure 4.2 is an excellent illustration of his argument on the structural crises of the accumulation process. Its presentation in this section will give content to the basic argument involved
Impediments to accumulation refer to "the process by which a given form of accumulation progressively becomes non-reproductive" (Wright, 1978:166). Structural solutions to the impediments of accumulation refers to the "ways in which the accumulation process is transformed to re-establish a compatible relation with the forces/relations of production" (Wright, 1978:166).

Class struggle and competition among capitalists transform both the articulation of forces and relations of production, and the forms of accumulation. Also, class struggle and competition mediate the very process of limitation that the articulation of forces/relations of production have over the forms of accumulation. When the forms of
accumulation fall out of the "limits" set by the articulation forces/relations of production, a structural crisis emerges that "demands" a solution. Each structural solution is not an absolute and complete solution. Residuals of the structural crisis may persist into the new structural relation, which has in itself the seeds for new and original structural crisis.

Initially, it was said that the lack of consensus among Marxists over the nature of the crisis of extended reproduction (crisis of capitalist accumulation) gave way to the emergence of different arguments and/or theories. However, as the "long waves" explanation (basically in the work of Wright, 1978) argues, the five different explanations complement each other. The long-run tendency of the organic composition to permanently rise (Mandel, 1975:131-132) has not been confirmed by empirical evidence (Rowthorn, 1976). More likely is the occurrence of different obstacles to accumulation at different phases of capitalist development (Mandel, 1975; Wright, 1978). Mainly in developed economies, the growth in productivity has tended increasingly to be one of the major difficulties in capitalist accumulation (Mandel, 1975) which per se tends to exert pressure on the state to intervene more decisively in the process. The state's promotion of research and development for both the industrial and agricultural sectors of the economy is an attempt to ease that difficulty and consequently fulfill what O'Connor (1973) calls the accumulation function.

In conclusion, Mandel (1975) broadens our understanding of accumulation as an exceedingly complex and contradictory process that cannot
be captured in a single formula. Like Mandel, Wright (1978) attains a broader view of the accumulation process, but then proceeds to fit the diverse sides of the logic of accumulation into social processes—structured by the social relations of production—and thereby return the various arguments (or "ideas") to their origin, social practice.

Hodgson (1974:64) pre-dates Wright's contribution when he writes:

Fundamentally, the accumulation of capital is the reproduction of capitalist social relations on an extended scale. It involves the extension of these relations over all other subordinate modes of production, which become destroyed or subsumed by capitalism, and the intensification of these relations ...

Essentially, behind the ebb and flow of accumulation and its contradictions, crises and crisis resolutions is a structure of class relations that gives definitive shape to accumulation. Thus, if accumulation implies the structuring and restructuring of social relations, then a picture of accumulation is incomplete without attention to the social relations that accumulation reflects.

The Relation of Capitalist Accumulation to the Creation of Agricultural Research Technology

Each one of the arguments over the nature of crises in the capitalist accumulation process sets the foundations for the elaboration of the basic hypothesis of this dissertation. This hypothesis assumes the following format:

Hypothesis 4.1: Over the years, changes in the forms of accumulation in Brazil have led to changes in the structural limitation that these forms impose on the creation of
agricultural research technology promoted by state institutions.

It should be noted that in linking accumulation of capital to the creation of agricultural research technology, Hypothesis 4.1 does not assume that all agricultural technology in Brazil is created internally. In reality, a large part of the scientific work (more for some agricultural commodities than for others) consists in adapting imported technologies to the diverse Brazilian regions of agricultural production. Hypothesis 4.1 only focuses on that part of agricultural research technology that is made and/or adapted internally. The essential dynamic component of the Brazilian technological terrain (agricultural or not) is not entirely found inside its frontiers. This fact reveals that the Brazilian dependency on the central capitalist economies extends to the technological terrain. The major objective in the formulation of Hypothesis 4.1 is to focus attention on the internal dynamic of the forms of accumulation in Brazil to understand the complex process that defines those agricultural research technologies which are impossible at a given moment and that also determine the relative likelihood of those which are possible. Thus, based on Hypothesis 4.1, a simplified model of determination can assume the format presented in Figure 4.3.

The production of agricultural research technology needs to be compatible with the characteristics of the reproduction process. All things remaining constant, the allocation of funds for agricultural research can continue or even increase so long as the creation and
development of agricultural research technology continues within the 
limits set by the forms of accumulation. These limits imply that cer­
tain forms of creation and development of agricultural technology have 
been excluded entirely and some possible forms are more likely than 
others to be created and developed. Figure 4.4 below tries to elabor­
ate graphically the structural limitation of Hypothesis 4.1.

Figure 4.3. Simplified Model of Determination of the Creation of Agricultural Research Technology.

Forms of Accumulation in Brazil

Figure 4.4. Limits of Structural Possibilities for the Creation of Agricultural Research Technology, at Moment T.

In Figure 4.4, R₁ to Rₙ represent the possible forms of technology 
that can materialize on the basis of scientific knowledge available at
that precise moment T. However, the issue of the materialization of any possible technological form operates within the constraints and possibilities of the given social setting. In this case we are putting forward the form of accumulation as the central element of the social reality that sets the limits within which the possible forms of technology materialize. Without those limits present in moment T, the scientific knowledge accumulated at that very moment T could make all those options from $R_1$ to $R_n$ (and not only $R_4$, $R_5$ and $R_6$) possible. In Figure 4.4, all forms of $R$'s that are out-of-limits are constrained, to be created and developed by the particular forms of accumulation of capital at that precise moment T.

As the terms of Hypothesis 4.1 are not static, changes in the form of accumulation of capital imply shifts in the limits such that agricultural research technologies that were constrained at moment T should possibly be realized (created) at moment $T + 1$. This shift of limits is illustrated in Figure 4.5.

At moment $T + 1$, $R_4$ is no more a concrete possibility. The possible developments of $R$ range now from $R_5$ to $R_8$, $R_5$ being an extremely contradictory and polemic limit in relation to which the intensity and strength of the effects of class struggle within the state will decide about its possible realization. This consideration about class struggle and the state is crucial. It brings about an important category of selection within the real possibilities, i.e., the state. The mechanisms of selection concretely determine ranges of outcome or even specific outcomes. These mechanisms of selection are what Wright (1978:17)
The principal debate about the state is not that between Marxists and non-Marxists. The more rich and challenging debate is that which occurs within the Marxist tradition itself. The discussion that follows about the state has three major objectives: (1) to assess the role the state plays in capitalist societies; (2) to understand why and how the state intervenes within the capital accumulation process and (3) to delineate the contours of how the state exercises influence in the very
process of creation of agricultural research technology. Since the
core of the debate on the state has mainly been concentrated within the
confines of advanced capitalist societies, an attempt to follow the de­
velopment of the theory of the state in "non-advanced" capitalist so­
cieties (mainly in Latin America) will be made.

Non-Marxist Theories of the State

The purpose of presenting non-Marxist theories of the state is to
give a compact picture of each major argument and not to be exhaustive
in the presentation. The aim is to present a contrast to the Marxist
view and not a defense or a systematic critique of each element. This
critique will be implicit in the form of exposition itself.

The major non-Marxist treatments of the state are given by the
pluralists (such as Bentley, 1967; Tocqueville, 1945; Dahl, 1961; Easton,
1971), structural-functionalists (such as Parsons, 1951, 1960, 1964;
Davis, 1949), elite theorists (such as Pareto, 1963; Mosca, 1939; Schum­
peter, 1950; Mills, 1957), and the so-called "group pressures" theorists
(such as Lipset, 1960). There is a certain degree of arbitrariness in
pigeonholing those different contributions into such general categories
as pluralist or structural-functionalist. The logic behind this classi­
fication is in emphasizing those points that have received a more syste­
matic treatment. It is perfectly justifiable to consider all the dif­
ferent developments as having a pluralist methodology. The emphasis on
overt conflict and on decision-making (to be commented on below) is
evidence of this methodology.
The basic pluralist proposition is that the state is the result of conflicting pressures of different groups in society. What makes up society is the summation of different interest groups. A particular state outcome is the consequence of negotiation and bargaining among these different interest groups. All alliances among different groups are temporary with new alliances and compromises signifying a new state outcome (policy). From this comes the conclusion that capitalist society is essentially democratic.

The structural-functionalists' relation of structure to process is founded on the so-called AGIL model. It is argued that processes in any social system are subjected to four functional imperatives: adaptation (A), goal attainment (G), integration (I), and latency (L). The goal attainment problem can be defined as that of keeping the action system moving toward its goals. In the structural-functional approach, those four analytic functional imperatives or problems can be examined at both a micro-analytic and a macro-analytic level. At the macro-analytic level, the G-sub-system is the polity, the A-sub-system is the economy. This latter sub-system (the economy) produces wealth and income, the former sub-system (the polity) uses wealth and income for the attainment of system goals. Within the Parsonian universe, the allocation of resources is the function of the Economy, and the distribution of income is the function of the Polity. Thus, "the goal of the polity is to maximize the capacity of the society to attain its system goals,
i.e., collective goals. We define this capacity as power as distinguished from wealth. [wealth is] an ingredient of power ..." (Parsons and Smelser, 1956:49).

Thus, the state in the Parsonian conception is the social institution delineated to obtain the goals of the people in society and not subject to control by any existent group or class. The concentration of power in advanced capitalist societies is both inevitable and desirable. This concentration indicates dynamism of a mature industrial society and is the functional need to achieve the desirable goals which lead to that inevitable and desirable concentration of power in capitalist society. The democratic character of the capitalist state is made explicit by the systematic electoral process and by the realization of society's goals.

The elite theory holds that all societies are divided between a ruling elite and passive masses that are easily manipulated by the elite. The explanation for the existence of a ruling elite is found in the inner drive for power itself, which is present in that very same elite. The state, thus, materializes the elite interests.

"Group pressures" theorists emphasize the role played by social groups in the determination of the political attitudes and overt behavior of the individuals. These social groups form a strong defensive wall that protects the individual from the elites' direct influence. The individual in social groups assumes the values, norms and interests of the group as its own. There is, thus, a cultural protection "against"
elite's manipulation of the non-elite groups. The state within this conception is a variant of the pluralist conception of the state.

These non-Marxist perspectives of the state have been criticized on different grounds (Wolff, 1968; Lowi, 1969; Bachrach and Baratz, 1970). One of the more penetrating critiques of these theories was made by Lukes (1974). In his methodological criticism, he divides these theories into two broad views, the one-dimensional and the two-dimensional view of power. In the former view (e.g., Dahl, 1961) the object of study is the concrete, observable behavior. It is assumed that the study of specific outcomes facilitates the observation of "who actually prevails in community decision-making" (Poslby, 1963). The whole idea or assumption is that "decisions" involve "direct," actual and observable conflict. Each decision is a decision about issues in selected "issue-areas," and those issues involve actual conflict (see Lukes, 1974:12-13). In the two-dimensional view (e.g., Bachrach and Baratz, 1970) the object of study is not only decision-making but also nondecision-making. This nondecision-making is the "means by which demands for change in the existing allocation of benefits and privileges in the community can be suffocated before they are even voiced; or kept covert; or killed before they gain access to the relevant decision-making arena; or, failing all these things, maimed or destroyed in the decision-implementing stage of the policy process" (Bachrach and Baratz, 1970:44). Nondecision, thus, is a form of decision that the decision-maker does in favor of his/her values or interests.
Recognizing the methodological advance of the two-dimensional over the one-dimensional view of power but criticizing the two-dimensional view for its methodologically individualist view of power and its association of power with actual, observable conflict, Lukes (1974) introduces what he calls a three-dimensional view of power.

The three-dimensional view of power "allows for consideration of the many ways in which potential issues are kept out of politics whether through the operation of social forces and institutional practices or through individuals' decisions" (Lukes, 1974:24). The emphasis in this new methodological perspective is not only to focus on observable (overt or covert) conflict, but mainly on "latent conflict, which consists in a tradition between the interests of those exercising power and the real interests of those they exclude" (Lukes, 1974:24-25). Issues and potential issues, subjective and real interests form the methodological concerns of Lukes' three-dimensional view of power.

In all of the above perspectives of power and the state, the notion of interest ends up as a basic one. The three-dimensional view of power "maintains that men's wants may themselves be a product of a system which works against their interests, and, in such cases, relates the latter to what they would want and prefer, were they able to make the choice" (Lukes, 1974:34). This notion of interest radically differs from the pluralist conception of interest. Pluralists' investigation of preferences identifies preferences with subjective interests. This identification is the basic methodological constraint of the
pluralist approach and the major obstacle to a reasonable methodological and theoretical treatment of the conversion of preferences to issues (Balbus, 1971).

Subjective interest is that which relies solely on the individual without taking into consideration objective conditions and determinants.

On the subjective meaning of the term, "interest" is equivalent to "interesting;" if a person is said to have an interest in something, it is because he finds it interesting or likes it. "Interest" in this sense is purely subjective because it refers to a psychological state in the mind of the person who is said to have the interest. If a person says he has an interest in music, meaning that he finds music interesting or that he likes it, it is impossible to bring any evidence to bear which will demonstrate that he is "wrong." (...) an individual's subjective interests are not merely given, or randomly generated, but rather are systematically determined by the way in which his life changes are objectively affected by objective conditions (Balbus, 1971:152-153).

On the other hand, objective interest "refers to an effect by something on the individual which can be observed and measured by standards external to the individual's consciousness" (Balbus, 1971:152).

... when we say an individual has an "interest in" something we mean that he has a stake in it or is "affected by" it. In this objective sense of the term the existence of the interest is not contingent upon the individual's awareness that he has the interest, i.e., upon any psychological state in the mind of the individual. A person may be affected by something whether or not he realizes it; hence evidence can be marshalled to demonstrate that an individual has an interest even if he is not aware of it or even that what an individual thinks is in his interest is in fact not in his interest (Balbus, 1971:152).

The problem of interest and the distinction between subjective and objective interest is a fundamental one in Marxist theory in general and in Marxist theories of the state in particular.
Marxist Theories of the State

In Marx's work there is no systematic and complete theory of the state. The elements of his theory are scattered throughout his contributions, particularly to be found in *The Eighteenth Brumaire of Louis Bonaparte* and in the *Manifesto of the Communist Party*. The debate among Marxists on the content of this theory has enriched the current Marxist(s) conception(s) of the state and given birth to various "theories" stressing different sets of propositions. It is important to observe that in spite of their differences, there is a unified concern among these "theories," i.e., that these "theories have with specific modes of production, their conditions of existence and their effects on social formations" (Jessop, 1977:369). In his analysis of the recent theories of the capitalist state, Jessop (1977:353-354) considers a Marxist theory of the capitalist state adequate to the extent that "(a) it is founded on the specific qualities of capitalism as a mode of production, (b) it attributes a central role to class struggle in the process of capital accumulation, (c) it establishes the relations between the political and economic features of society without reducing one to the other or treating them as totally independent and autonomous, (d) it allows for historical and national differences in the forms and functions of the state in capitalist societies, and (e) it allows for the influence of non-capitalist classes and non-class forces in determining the nature of the state and the exercise of state power." The theories to be discussed below take seriously these general characteristics for identifying an adequate Marxist theory of the capitalist state.
Instrumentalists

The fundamental conception among the instrumentalists is that the capitalist state directly serves the interest of the "ruling class." The state is seen as "an instrument in the hands of the ruling classes for enforcing and guaranteeing the stability of the class structure itself" (Sweezy, 1942:243).

The instrumentalist's approach to the state is a reaction against the pluralist conception that views the state as the result of the various social groups that make up society and which bargain with (potentially) equal strength. The point now with the instrumentalists is that the primary function of the state is to uphold class domination (Sweezy, 1942:244), i.e., the state's function is to secure the mechanisms of social reproduction and capital accumulation. The equal competition between capital and labor, capitalists and workers assumed by the pluralists is strongly rejected. Miliband (1969:148), beginning a chapter titled "Imperfect Competition," argues that what is wrong with pluralist-democratic theory is not its insistence on the fact of competition but its claim (very often its implicit assumption) that the major organised "interests" in these societies, and notably capital and labor, compete on more or less equal terms, and that none of them is therefore able to achieve a decisive and permanent advantage in the process of competition.

And in Chapter Four, "The Purpose and Role of Government," Miliband says

Whenever governments have felt it incumbent, as they have done more and more, to intervene directly in disputes between employers and wage-earners, the result of their intervention has tended to be disadvantageous to the latter, not the former. On innumerable occasions, and in all capitalist countries, governments have played a decisive
role in defeating strikes, often by the invocation of the coercive power of the state and the use of naked violence; and the fact that they have done so in the name of the national interest, law and order, constitutional government, the protection of "the public," etc., rather than simply to support employers, has not made that intervention any the less useful to these employers (Miliband, 1969:80).

In spite of having shown both that the capitalist class is not a monolithic class based on a single economic interest, but a social force that has internal contradictions, and that the state has a class nature, the instrumentalists failed in going beyond the pluralist framework. The ties between the ruling class and the state are sharply over-emphasized, while the contradictions and constraints of the capitalist system are conceived of as epiphenomena. There is in this perspective of the state an evident reductionism: the reductionism of the state apparatus to state power.

Structuralists

The structuralists are characterized by their emphasis on the structural level of a capitalist social formation. The broad proposition is that the elements of the structure broadly determine the functions of the state. The state is considered as a function of state power and is formed by the (repressive) state apparatus (such as government, administration, army, police, courts and prisons) and the ideological state apparatus, "a certain number of realities which present themselves to the immediate observer in the form of distinct and specialized institutions" such as religion, education, family, law, politics, trade unionism, communication
(such as press, radio and television) and culture (such as literature, arts and sports) (see Althusser, 1971:140-148).

The reproduction of the conditions (relations) of production are secured by both apparati, the repressive and the ideological. Any one of these state apparati cannot be confused with the other. The ideological state apparati are a plurality whose unit is not immediately visible.

Whereas the (repressive) State apparatus constitutes an organized whole whose different parts are centralized beneath a commanding unity ..., the Ideological State Apparatuses are multiple, distinct, "relatively autonomous" and capable of providing an objective field to contradictions which express, in forms which may be limited or extreme, the effects of the clashes between the capitalist class struggle and the proletarian class struggle, as well as their subordinate forms (Althusser, 1971:149).

These Althusserian formulations of the state were greatly improved by Poulantzas (1969, 1976, 1978a, 1978b, 1978c). To Poulantzas (1978c), the state is at the same time distinctive from (in the sense of separation) and involved with (in the sense of presence-action) the economic sphere. The forms of these distinctions and involvements are marked by the totality of economic, political and ideological determinations (mode of production). The relations of production delimit the field of the state, but the state "has a role of its own in the formulation of these same relations" (Poulantzas, 1978c:25). The relations of production which find expression in class powers consist of the dual relationship of economic property (the real economic control of the means of production) and possession (the capacity to put the means of production into operation).
In Poulantzas (1978a, 1978b) the state (state apparatus) is not an entity that has an intrinsic instrumental relation. Rather, it is the materialization and condensation of class relations. In this sense, the state apparatus is related to, but cannot be confused with, state power. This means that the different functions of the state apparatus (economic, political, ideological) in the reproduction of social relations depend on the classes and class fractions which occupy the terrain of political domination. This political domination is, thus, an intrinsic part of the state apparatus. Within this conception, state policy is situated in the context of the functioning of the capitalist system as a whole. Poulantzas (1978a:26) argues that "it is state power, directly articulated with the class struggle, that determines the role and the functioning of the state apparatuses." For him, and this is a basic point, "any analysis of a social formation must take into direct consideration both the relations of class struggle, the power relations, and the state apparatuses which materialize, concentrate and reflect these relations" (Poulantzas, 1978a:27). As the central site of the exercise of power, the state has the characteristic of being relatively autonomous. But this characteristic of relative autonomy is not an invariant feature of the capitalist state. The form of relative autonomy is dependent on the degree of both the contradictions within the various classes which form the power bloc and the class struggle between capital and labor. Relative autonomy means that the state and state policy are never completely independent from active control by the capitalist class nor completely free from any structural constraints. Gold, Lo and Wright
present the absence of an explanation of the social mechanisms which actually generate a class policy which is compatible with the needs of the system as one of the major deficiencies in Poulantzas' formulation. And this deficiency permeates the structural position as a whole.

Differently from Poulantzas (1978a, 1978b), Offe's (1974) contribution is in developing a theory of the mechanisms within the state which give it a class character. However, this class character of the state should not be confused with the instrumentalist argument. In fact, there is no guarantee that the state can secure all the needs of capital at one time. State-organized governance is viewed as a selective, event-generating system of rules. By selectiveness is understood "the non-accidental (i.e. systematic) restriction of a scope of possibility" (Offe, 1974:38-39). The operation of these selective mechanisms (basic to the understanding of the state) serves three basic functions: (1) negative selection, which excludes anti-capitalist interests from state activity; (2) positive selection, which gives priority to policies linked with the interest of capital as a whole; and (3) disguising selection, which gives to the state its appearance of class-neutrality. To Offe (1972:144), the reality of the capitalist state is an unrealistic attempt, i.e., "there is neither visible nor to be anticipated a strategy that actually does reconcile (the different and contradictory functions of the state) and thus achieve a balanced integration of the state and the accumulation process." The different and contradictory functions of the state are derived from (a) the exclusion of the capitalist state from accumulation,
(b) the state's necessary function for accumulation, (c) the state's dependence upon accumulation and (d) the state's function to conceal and deny (a), (b) and (c).

To Wolfe (1974), the study of the state faces a two-way process: (1) the state includes the extraction of something from people, and (2) it includes an imposition on people of something alien to them (p. 148). And for him, the first process is as worthwhile to study as the second one. Wolfe's (1974) major concern is the critique of the current explanations of why people accept their own exploitation. To him, these explanations are no longer adequate. In this century, he argues, alienated politics is defined as "the process through which people in similar positions are separated from each other, forced to compete instead of to co-operate" (Wolfe, 1974:148). On the other hand, the capitalist state is defined as "the political institution which claims primary responsibility for reproducing alienated politics, that is, for maintaining a political system based upon the extraction and imposition of power from people" (Wolfe, 1974:149). Government appears as the easily identified existential reality of the state.

In relation to the disagreement among Marxists over whether surplus value or alienation is the modal point of the theory, Wolfe (1974) argues that the difference in vocabulary between late and early Marx is merely an improvement on what was already formulated in the theory and not an epistemological break as defended by Althusser (1977, 1971) and Poulantzas (1978a, 1978b). At this point his argument is closer to that of Walton and Gamble (1972). Wolfe (1974) claims that in the early
writings on the state there is an analogy between the economic and the political realms. The two "natural" phenomena in the economic realm are man and work, while in the political realm the two "natural" phenomena are men and community. His argument is that in capitalist society, the process of work produces an object which reverses itself against man as alienated labor and oppresses him ... But the need for community, given alienated economic relationships instead creates an object called the State, which returns in alienated form to man as his oppressor. Therefore, as work expresses alienated labor, the State is the expression of what the German Ideology calls "illusory community" or alienated politics (Wolfe, 1974:148).

Thus, in Wolfe (1974), alienated labor and alienated politics are different forms of distortions. The former is a distortion of people's need to engage in productive activity, and the latter is a distortion of the community.

The State and its Mode of Determination on the Creation of Agricultural Research Technology

The concept of the state developed by such theorists as O'Connor (1973), Wolfe (1974), Poulantzas (1978a, 1978b), and Offe (1972, 1974) has sought to build a necessary and systematic link between economic and political processes. Particularly for Wolfe (1974), Poulantzas (1978a, 1978b) and Offe (1972, 1974) the linkage does not in any sense mean a collapse of political processes into economic ones, but rather two distinct but not entirely functional aspects of a larger social reproduction process. This reconceptualization of the principal components of the social reproduction process makes possible the insertion of the creation of agricultural research technology in a manner that more
adequately taps not only the structural conditions for their creation, but also the precarious nature of those conditions.

One hypothesis that this work formulates, but that will not be examined empirically, is presented below. The purpose of its formulation in this chapter has at least two major aims: (1) to facilitate the understanding of the basic theoretical mechanisms which act simultaneously with those discussed in Hypothesis 4.1, and (2) to identify key issues that deserve closer attention for further investigations in specific capitalist social formations. 7/

Hypothesis 4.2: Upon a shift in the balance of class forces in the state, a corresponding shift will occur in the range of possible forms of agricultural research technology concretely selected from within the limits set by the accumulation process.

In other words, given a certain and fixed form of accumulation, a shift in the balance of class forces can have the effect of selecting out a "wider" or "narrower" range of concrete forms of agricultural research technology. It follows from our analysis of the capitalist state serving two general functions, accumulation and legitimation, that a "narrower" selection process would mean a narrow range of forms of agricultural research technology that serve accumulation, while the selection of a wider range would mean the inclusion of policies and interventions of the state that would develop forms of agricultural research technologies to serve in limited ways a legitimation function as well.
This mechanism of selection performed by the state which functions to set limits on the creation of agricultural research technology within the limits already fixed by the accumulation process is shown in Figure 4.6.

Due to the structural mechanism of selection played by the state, the range of possibilities for the creation of $R$ changes from $R_5$ to $R_8$ in Figure 4.5 to the shaded area in Figure 4.6. This mechanism of selection is not the result of a necessary instrumental action of the state. It is important to recall at this point that the relative autonomy of the state (which is not an invariant feature) directly depends
on (1) the degree of the contradictions within the different classes which form the power bloc, and (2) the degree of the contradictions of the class struggle between capital and labor. These two sources of contradictions are the major force in determining the content of the mechanism of selection. This justifies the fact that in spite of being a basic and powerful source of constraint, accumulation is not necessarily the immediate determinant of the selection mechanism of the capitalist state in relation to the creation of agricultural research technology. One of the basic functions of the state is to give conditions for capitalist accumulation, and the content of agricultural technology is one of these conditions. In making possible the conditions for capital accumulation, the capitalist state is also making possible the conditions for its own existence. In fact, it depends upon the presence and continuity of the accumulation process.

Hypotheses 4.3.1 and 4.3.2 (which also will not be empirically examined in this work) provide a broader understanding of the structural mechanisms which act together to shape the creation of agricultural research technology. The content of these hypotheses is:

Hypothesis 4.3.1: Changes in the forms of accumulation will lead to shifts in the limits imposed by accumulation on the possible forms of state policies/interventions.

Hypothesis 4.3.2: Changes in the forms of accumulation will lead to shifts in the limits imposed by accumulation on the possible forms of state structure.
The kind of state structure is to be distinguished from the forms of state intervention in that the former refers to the principal mode of organization of the state and the latter refers to the activities of the state. Advanced forms of accumulation may be seen to dissolve old limits and impose new limits on the structure of the state in such a way that, for example, a form known as "parliamentary politics" is outside those limits and another form, such as "managerial technocracy," falls within the new limits. Forms of state intervention, on the other hand, cannot be reduced to the state's formal structure. They can be shown to be two separate and distinct processes in cases where, for example, class struggle may have the effect of bringing more groups into the basically unchanged state apparatus, thereby redirecting the forms of state intervention, within, of course, limits imposed by the structure of the state itself.

Hypotheses 4.3.1 and 4.3.2 indicate how it is not possible for the state to be mechanistically determined by accumulation. Given variation of the state within structural limits, Hypotheses 4.4.1 and 4.4.2 (given below) point to two important ways (by way of changes in state structures and policies) that the state has an impact on the creation of agricultural research technology.

Hypothesis 4.4.1: Changes in state structure will signal changes in the way the state mediates the process of limitation imposed by the forms of accumulation on the creation of agricultural research technology.
Hypothesis 4.4.2: Changes in state policies/intervention will signal changes in the way the state mediates the process of limitation imposed by the forms of accumulation on the creation of agricultural research technology.

Forms of accumulation will have very different consequences for the creation of agricultural research technology depending on the relationship of the state to the forms of accumulation. In our discussion on the state we have seen that the state is a capitalist state in two senses: it is both constituted by accumulation and implicated in the process. Given that central to our concept of accumulation are structurally antagonistic social relations, it follows that the state—as the condensation of class relations (to use Poulantzas' expression)—can never be completely "functional" to the interests of capital. Herein lie the structural conditions for a range of possible ways in which the state can position itself in relation to accumulation and thereby affect the very direct consequences that accumulation has on the creation of agricultural research technology.

An example of the state's mediating role may help show how the state can redirect (or change) the consequences of the forms of accumulation on the creation of agricultural research technology. The state has apparati that function to receive information in the form of needs, interests, etc., and to disseminate information to the agricultural sector. The accumulation process, underpinned by a change in class relations, has a range of possible "needs." But the kind of information received by the state and the extent to which it is acted upon vary
according to the balance of class forces in the state. Because of the various ways in which the state can position itself to accumulation (favoring one class or class fraction over another), the state can shape the ways in which accumulation affects the creation of agricultural research technology. In Brazil, the extension service coordinated by EMBRATER (Brazilian Corporation of Technical Assistance and Rural Extension) is one of the elements of the state apparatus which not only carries innovations to farmers, but makes possible the flow of information from farmers to the research centers (say, EMBRAPA) as well. Let us suppose, for example, that to the extent that this extension service concentrates its attention and resources on large- and medium-scale farmers, the segment of small and "subsistence farmers" will find it more difficult to be "heard," in terms of their technological demands, by the agricultural researchers who actually create and develop agricultural technology. This example is placed here to describe one of the different forms in which state mediation determines the terrain where the forms of accumulation act in determining the relative likelihood of various possible forms of the creation of agricultural research technology. Thus, the action of state policies or of the state apparatus can perform that mediation role by favoring some forms of accumulation over others by transferring signals from farmers to the source of generation (such as EMBRAPA) of agricultural research technology.

The complexity of the model of determination presented in Figure 4.7 puts together the major structural relations identified in Hypothesis
4.1 to 4.4. Its utility resides in laying out in an explicit manner the logic of the relations directly and indirectly explored in this study.

Figure 4.7 shows that the forms of accumulation put limits on both the state and the creation of agricultural research technology.

It must be remembered that the forms of accumulation do not have an existence of their own. They are transformed by class struggle and competition among capitalists and limited by the articulation of forces and relations of production, as Figure 4.2, taken from Wright (1978:165), shows in detail. In the relation of limitation that the forms of accumulation place on the creation of agricultural research technology, the role of the state is characterized by shaping the consequences of that very relation. The state does not at all function as an "intervening" variable in the sense that it is merely causally situated between the forms of accumulation and the creation of agricultural research.
technology. Rather, Figure 4.7 depicts the state as determining the terrain on which the forms of accumulation and the creation of agricultural research technology operate. But the importance of the state is also viewed as concretely determining ranges of outcomes, i.e., as concretely selecting outcomes within a structurally limited range of possibilities set by the forms of accumulation (see also Figure 4.6). The complexity of the model of determination presented above has encouraged the empirical investigation of a simpler but more fundamental version that will focus on the relationship between accumulation and the creation of agricultural research technology (and to exclude, therefore, from empirical analysis, Hypotheses 4.2 through 4.4.2).

In terms of social phenomena—or rather, the more visible processes involved in the creation of agricultural research technology—the role of the state cannot be taken from the picture. Thus, we show in several hypotheses what the actual picture of events may look like. Still, at a more fundamental level, the accumulation process shapes the creation of agricultural research technology, as we tried to point out in the discussions on accumulation and the state. This more fundamental relation makes it highly dubious to view the state as an autonomous policy-making body and to put faith in simple solutions such as to "change the minds of policy-makers" in order to resolve the problems facing Brazil today. Before facing the analysis of the limitation that the forms of accumulation place on the creation of agricultural research technology (Chapter 6), discussion of agricultural research technology itself needs to be done. This is the task of the next chapter.
FOOTNOTES FROM CHAPTER 4

1/ Althusser (1977:34-40) conceptualizes the real object as independent from the process of knowledge. For a critique of Althusser, see Giannotti (1971).

2/ To facilitate an analysis of the circuit of capital, Marx identified two component spheres of activity: production and circulation. "Production is the activity of setting to work means of production and labor power to produce commodities" and "circulation refers to the activity of selling commodities for money and buying commodities as inputs" (Fine and Harris, 1979). Three distinct but related functions comprise the two spheres of activity: production, exchange and distribution. The strength of Marx's argument lies in showing the unity in domination of these three distinct processes in the circuit of capital. Rather than treating production, distribution and exchange as separate steps in the economic system stacked logically side by side, Marx demonstrates how distribution and exchange can also be production (see Marx, 1973:115-238).


4/ For a critique of Balbus (1971) see Haurt and Leibfried (1972).


6/ On Poulantzas' major works see, for example, Jessop (1980).

7/ This dissertation does not claim to be the last word on how to pose the problem of the creation of agricultural research technology. Rather, it aims to give a limited but essential step to a better understanding of the structural mechanisms that shape the creation of agricultural research technology. As revealed in Chapters 1 and 2, this work rejects the assumption that social relations can be abstracted from economics, i.e., an economic structure consisting of forces and relations of production. The presence of this rejection is viewed in the content of Hypothesis 4.1 and is reaffirmed in the proposed hypotheses that follow in this chapter.
Writing about state, capital and crisis in Brazil, Munk (1980:41) observes that "the 'relative autonomy' of the dependent state, for example in periods of imperialist crisis, must be established for each historical conjuncture in relation to the class struggle, and not assumed as a theoretical a priori." See also Munk (1979).

The relationships we have postulated in Figure 4.7 are all unidirectional. This is not to say that modes of determination which go in the opposite direction are non-existent or even less important. See Chapter 5 for a preliminary two-directional model. Additional modes of determination in the reverse direction would be a proper object for future research.
CHAPTER 5

AGRICULTURAL RESEARCH TECHNOLOGY

This chapter aims to conceptualize agricultural research technology and, afterwards, to relate this concept to its output: a specific agricultural technology. Up to this point, the notion of technology as more than just a "thing" has been an undefended claim. If we were to accept specific agricultural technologies as pure and unmediated raw data, we could simply assign an appropriate name such as agricultural research technology in order to summarize the activity of producing and developing the knowledge of specific technologies. However, to assign appropriate names to a set of raw data is a small and insignificant aspect of conceptualization. To produce the concept agricultural research technology, it is necessary to understand agricultural research technology as a determined process both within a broadly defined social process and among other specific processes. Moreover, if agricultural research technology deserves the status of a concept, it must have its own specificity; otherwise there would be no object of study behind the name, and rather than refer to agricultural research technology, it would be more appropriate to focus only on its determinants. Conceptualization of agricultural research technology will thus involve two aspects: an elaboration of the inner nature of what is commonly called "technology" and an elaboration of its interconnections to other processes. For a concept in social science to be useful,
i.e. provide the conditions for yielding knowledge of social reality, it must have a real material content. Thus, the second aim of this chapter is to relate this concept back to its specific output, and within the limits set by the available data, construct measures of agricultural research technology that are consistent with the concept.

Agricultural research technology carries with it related notions of science and technology. Fundamental distinctions exist between science and technology, but the differences between technology and agricultural research technology are only of a general to specific nature. Agricultural research technology is only one aspect within a broader and more fundamental concept of technology. Although the difference between science and technology cannot be reduced to one of a general/specific nature, a discussion of the nature of science in relation to technology is nevertheless crucial for two reasons: (1) frequently science and technology are either used loosely and interchangeably or are collapsed into each other to form a single phrase "science and technology." In either case, there is little possibility of identifying their determinants; and (2) our conceptualization of technology presupposes a prior conceptualization of science, its inner nature and interconnections with other processes in the social reality.

Thus, the task of conceptualizing agricultural research technology demands elaboration of a hierarchy of concepts from which "agricultural research technology" represents a particular aspect produced within the constraints of these more fundamental concepts. Of course,
technology and science, and likewise agricultural research technology, represent a particular aspect which cannot be entirely abstracted from the social activity of human beings that makes possible their ongoing development. This idea is implicit to the discussion of science, technology and agricultural research technology in the abstract, but will be addressed directly by relating technology to the most basic determining structure of social relations in a capitalist society.

The exact nature of science and its precise interconnections with social reality are central issues called forth by the debate over the autonomy/lack of autonomy of science in society. A study on technology and its determinants does not need a full rendition of the many nuances in this most characteristic debate in the sociology of science. It is important to discuss only those more salient features of the debate pertaining to and leading into our concept of technology.

Basically, the debate has generated two divergent tendencies. One tendency is to treat science as if were free from the influence of social and historical conditions. Widely diverse masters of social theory such as Merton (1949), Popper (1959), Bachelard (1968), and Althusser (1975; 1977) range from being outright guilty of such a tendency to only lending themselves to such an interpretation. On the opposite end of the spectrum, another tendency is to reduce science to other social and/or technological processes. The idea of a nonsocial scientific knowledge (such as identified in the first tendency) simply cannot exist to authors so different as Bukharin (1971), Braverman (1974), Sohn-Rethel (1975), Pickvance (1976), Hodgkin (1976), Noble (1977), Aronowitz (1978),

Within the first tendency there are to be found widely varying definitions of science. Following Merton, Storer (1966:3) views science as

the organized social activity of men and women who are concerned with extending man's body of empirical knowledge ... The relationships among these people guided by a set of shared norms, constitute the social characteristics of science.

Merton's work (1949) was decisive in providing sociology with what became the "standard view" of science and which was later mirrored in Storer's definition. Merton (1949; 1957; 1963) elaborated a view of the normative structure of science by identifying six "institutional imperatives" (universalism, communism, disinterestedness, organized skepticism, originality and humility) derived from the subjective interpretations of scientists themselves. This view of science spread rapidly; its success was partly because it was a "common sense" approach to science and also because it probably supported the political ideology of American academics (King, 1971).

Unlike Merton (1949), Popper (1959) was concerned chiefly with establishing the objective criteria for science. The criterion Popper found to demarcate scientific from non-scientific activity was the necessity for the capability to falsify (or disprove) the theory built into the scientific activity itself. Following Popper, Lakatos and Musgrave (1970) uphold the rationality of science and agree for its
progressive nature by claiming that a science grows so long as it can predict new facts with some success.

Bachelard (1968) rejected the typically common sense approach of Popper and Lakatos. Instead, science was understood to be exclusively the domain of reason. Bachelard argued for a rupture between scientific work and ordinary experience. Similarly, Althusser suggests (see Althusser and Balibar, 1975:109, 113, 117, 145, 183 and Althusser, 1971:47, 129-30) that the theoretical function is not of itself a practico-social one, that to function as knowledge is not itself to function socially and that the only interest at work in the development of knowledge is interests internal to knowledge (knowledge for its own sake).

The principle shortcoming that all of the works mentioned above have according to those who tend to view science as an ideology is that there is no basis for ideological intervention into scientific activity. Merton's normative structure theory constructs a view that scientists are in pursuit of truth and their satisfaction is only derived from solving significant problems. But as Kuhn (1970)—see also Bohme (1977)—has argued, what are considered significant problems and their resulting solutions are largely the product of extra-scientific conditions (socio-cultural). Although Popper, Bachelard and Althusser are not addressing scientists per se, but rather the distinguishing content of science, their work leads easily to a super rational science within which "scientists" operate. With respect to science, Levy-Lebland (1976:136-175) distinguishes two sets of questions: those dealing with questions of power (political, military, economic, etc.) and those of
knowledge (epistemological or philosophical); the ideological components of a science are shown to be more effectively explored by examining questions of power.

Kuhn (1970) inverts the pure, rational view of science that is reinforced by Merton's (1942) normative structure theory and conceptualized by Bachelard and others by giving to science an underlying socio-historical dimension. For Kuhn, there are no intrinsic criteria by which to judge one theory "better" than another. The selection of a theory or a "dominant paradigm" in the stage of "normal science" rests with the scientific community. Scientific truth is relative to the conventions among scientists. In constructing a normal science by which there is no objective basis for truth, Kuhn provides little basis for a critique of science. Kuhn's formulation of normal science amounts to the construction of an ideology for science rather than any full and systematic analysis by which science is connected to social processes.

Marxist attempts have viewed science as a specific activity within social development itself (Bohme, 1977). Social development is the result of the dialectical movement of the forces and relations of production. With this point of departure, one of the major objectives in Marxist theory is to build those links between science and the broader socio-political processes that are absent from Kuhn's model and other models opposed to a pure science. The "view" of science depends largely on where science is located in the structure of social development and how some basic Marxist categories are conceptualized, in particular, the forces of production. When science is located in the superstructure, it
takes its place alongside ideology. Its subordinate position in development makes it no more than another ideology. When science is located in the economic structure and becomes a productive force, it sheds its subordinate role alongside ideology. In those cases where "forces" are conceptualized as things and the forces are seen to play the pivotal role in social change, then the tendency has been to assign to science a neutral character and a liberating role. If the qualitative aspect of the forces is emphasized and the relations of production are held to play the decisive role in social development, then science is viewed as a practice whose inner nature and its connection to the fundamental structure of the social relations in society constitute a relatively autonomous process. Before turning to a view of science that proposes an alternative to the problematic of either collapsing science into ideology or raising science to the level of neutrality and assigning it a liberating role, the divergent tendencies themselves will be discussed.

Science at the Superstructural Level

The classical case of locating science at the superstructural level was "Lysenkoism" which represented a widespread attempt to build a "socialist science" in the Soviet Union over several decades (1930's-1960's). Essentially, Lysenko's genetic theory was the product of the direct use of dialectics as a method of research. The whole affair between social doctrine (reflected in the dialectical method) and physical science
brought into view the inadequacies of collapsing ideology, social theory and physical science all into one metaphysical principle.

Schmidt (1971) argues that raising dialectics to the level of a metaphysical principle can be traced to Engels, and in particular his *Dialectics of Nature*. According to Schmidt (1971:57), Engles abstracted the moments of the dialectic from the concrete historical situation to produce "fundamental laws" which stand over against the natural and social reality. But the dialectics were never intended to be a direct method of research which is then applied to nature on the one hand and to society on the other. At most, dialectics are intended to be a mode of presentation or interpretation of the world, and this is clearly distinct from a mode of inquiry into the patterns of determination of either natural or social processes (Schmidt, 1971:57). Furthermore, uprooting the dialectic from its material base destroys the unity of the world. This fundamental unity of man and nature— distinctions within a unity (to be returned to later)— marks the impossibility of a natural "socialist" science. On the one hand, nature has its own mechanisms of operation that cannot be reduced to social mechanisms or be raised up to abstract metaphysical principles. On the other hand, nature never appears in its raw "natural" state, but rather, appears as an object for man and mediated by him (Schmidt, 1971:50-67). A natural socialist science cannot therefore be constructed in isolation from the social reality that mediates that very process of investigation and discovery.

Some outlandish conclusions stem from the logic outlined above for reducing natural science to competing ideologies. For example, trees
that were planted closer to one another were argued to grow better on the assumption that trees (not unlike individual persons as social beings) need other trees in order to grow. In short, the construction of a so-called socialist science by transforming the very method of inquiry denies science its own distinctiveness.

An additional consequence of locating science at the superstructural level alongside ideology is that the content of science is then seen to be raised up exclusively from the social relations of production. A radical shift in the fundamental structure of the social relations, let us say from "capitalist" to "socialist" relations, spells a total transformation in science. Science having no content of its own, virtually dissolves to be replaced by a technology of the past.

In reaction to the above view, Feenburg (1977) criticizes Fleron's (1977) acceptance of the Chinese model which considers technological development "a summation of labor in action" and eschews a science-based technology. In the Chinese model, science is entirely collapsed into technology; the only available option is to eliminate the science-based technology and revert to a technology of the past. Following Fleron (1977), Leiss (1977:135) writes:

... socialism must institute a long-range strategy to reduce (not eliminate) the scope of marketing activity and promote opportunities for direct production for use (for example, in craft activities). To be sure, this form of production would be less "efficient" as judged by purely technical standards.

The mood that is anticipated in socialist relations is one of anti-science, since the very nature of science is seen to be born out of the capitalist social relations. Rose and Rose (1976:xvii) point out that
when locating science in the superstructure, science has no content of its own that is independent of the ruling class.

**Science as a Productive Force**

On the other side are those who view science as a productive force. When the productive forces are understood to be things and likewise, the quantitative aspect of the forces are considered more crucial than the qualitative aspects, the content of science and its relation to society take on a particular meaning that will be discussed presently.

Cohen (1978:45) provides a rationale for assigning science the status of a productive force. He argues concisely:

Labor power is a productive force and one dimension of labor power is productively applicable knowledge. It follows that scientific knowledge which is open to productive use is a productive force.

With science located among the productive forces, it is only a small step to assert the central role of science in the development of the productive forces and therefore a central role in the development of technology, i.e., a science-based technology. Cohen (1978) claims that science cannot be located in the superstructure because the superstructure consists of non-economic institutions of which science is not. Nor can science be ideology "since it is a defining property of ideology that it is unscientific" (Cohen, 1978:45).

While Cohen (1978) has produced, for Marx's theory of history, a highly impressive defense of the primacy of the forces of production thesis, his purpose was not to address directly the nature and function of science within that theory. Perhaps not as subtle and powerful in
their argumentation, other proponents of the primacy of the productive forces thesis (such as Bernal, 1939 and Feenburg, 1977) have, however, addressed directly the issue of science, its place and role in society, and its relation to technology.

Bernal (1939) located the dynamic of historical change within the productive forces. In their dialectical movement, the relations of production facilitate the development of the forces. The progressive levels of the productive forces provoke a non-functional and intolerable condition where the relations of production (e.g., private appropriation) can no longer support the expanding forces of production (e.g., increasing socialization of the means of production). A crucial point of argument for this position which Bernal reflects is that the productive forces, having an internal dynamic of their own, at a certain level call forth a particular set of social relations. Thus, if the productive forces have been developed under capitalist social relations, at a certain level of their development capitalist relations will become a fetter, and from this contradiction is the immanent emergence of socialist relations. This notion of the productive forces and their primacy over the relations of production leads to an optimistic view of the role of science in social development. Moreover, like the other "productive forces"—understood as things—science has an immanent expansion from which emerges a socialist science, i.e., a science for the people.
Feenburg (1977) is not as willing to argue for the immanence of socialism; an argument for the "possibility" of socialism takes its place. The basis for the possibility of socialism is rooted in a structural contradiction between the forces and relations of production; as the productive forces expand, there is a concomitant increase in the skill required to maintain and develop the technology. The human talents that are called forth in the development of the productive forces are increasingly incompatible with the drudgery and deskilling of work required by capitalist relations (that is, separation of mental and manual labor). Immanent to the pending structural contradiction is a concept of interest that is derived directly from that structure and is called "economic perceptions." Individuals located at various points in the structure will perceive their economic conditions differently, and of course, as the contradiction grows, the basis for an interest in socialism will grow as well.

We are here interested not in the general problems of Bernal's (1939) and Feenburg's (1977) works, but with the underlying logic in the conceptualization of the forces of production that leads to a particular conception of science, its relation to technology and to society.

First, the locus for the dynamic of social development lies with efficiency, while struggle and the conditions for struggle remain secondary aspects (see Feenburg, 1977:95). Scientific knowledge serves a productive use in its increasing control over nature. If efficiency is the decisive and immanent force behind social change, then its handmaiden, science, is necessarily neutral.
Second, when conceptualizing productive forces as things, the political and ideological elements are abstracted from the content of the productive forces to be related back to the forces, but this time in an external way. Therborn (1978) distinguishes two aspects of the productive forces that have received varying emphasis: the quantitative and the qualitative. He points out that an emphasis on the qualitative aspect demands consideration of the "different ways in which productivity is ensured" (1978:363). Along similar lines, Burawoy (1978) argues convincingly for the inseparability of the so-called "productive forces" from the ideological and political conditions that ensure productivity. By abstracting the political and ideological from the economic base (which follows from an insistence on productive forces as things), there is no such thing as a "technological imperative." Nothing is intrinsic to the technology that serves to reproduce political or ideological relations.

Taken together, the first and second points central to the primacy of the productive forces thesis produce a view of science that is neutral and a view of technology that is both science-based and inherently neutral. Although authors such as Feenburg (1977:108) explicitly state the non-neutrality of technology, there is provided in his approach no capacity for the investigation of that non-neutrality. A vague assertion on the possibility of socialism detracts from the investigation into the conditions of existence of capitalist relations—conditions of existence that are secured through struggle as well as on behalf of efficiency. Having been secured through struggle, those conditions are
always precarious (Burawoy, 1978:305). There is no reason to reduce all conditions for control over the production process to an opposition between mental and manual labor (as a condition for greater efficiency), as does Feenburg.

Science and Technology as Practices

Up to this point the positions in our discussion on the nature of science and its interconnection with society have fallen basically into two camps. The one camp asserts the specificity of science and its neutral role. The "neutral" role assumes an objective pursuit of knowledge in the Mertonian view, or for the Marxists who defend the primacy of the productive forces thesis, an "instrument" to be taken and adopted by socialism. The other camp reduces science to ideology and produces a socialist or capitalist science and the resolution in anti-science. This problematic detracts from the more crucial question of in what capacity science serves as a condition of existence for the reproduction of capitalist social relations. It is on this basis and within the constraints of our conceptualization of science that we can offer a distinctive concept of technology.

Science (and technology as well) are not "things" or "entities" pre-given and then subsequently made to fit into the social reality. Both represent distinctive human practices--particular and absolute dimensions of human activity. Practices refer to activities of transformation of some raw material to produce some product (outcome) through the use of some means of production within a structure of social relations. The constituent elements of the "practice" are: raw materials,
a transformative activity and a product. By definition, practices cannot be reduced to "social processes" in general. Rather, distinctive practices occur within and among other social processes. Practices have a dual nature. On the one hand they are inextricably linked to other social processes and in their connection become subsumed by them. On the other hand, practices are distinctive, i.e., have a specificity, which marks the irreducibility of that practice to any other social process with which it is inextricably linked. The specificity of the practice marks out the terrain on which struggle occurs for the moulding and adapting of that practice as a condition of existence for the reproduction of capitalist social relations. When we say that practices are irreducible to other social processes, we mean in the case of science (or technology) that these practices are never wedded permanently to capitalist social relations, but are, rather, separate and distinctive forms of activity subjected to struggle; through the outcome of this struggle practices serve in a certain capacity as a condition for the reproduction of the predominant social relations.

The concept that has been employed to express the notion of a distinctive practice inextricably linked to other social processes is relative autonomy. Science and technology represent relative autonomous sites. In contrast to the "reducibility" and "irreducibility" theses, the notion of relatively autonomous science accepts that economic practice in some fundamental sense defines the terrain upon which not only scientific, but other, practices occur. The word "relative" is crucial
in this context. It reveals the ways in which science or technology become conditions for economic practice.

The tasks that lie before us are to map out the dual nature of the concepts of science and technology as practices. It will be necessary to set forth the bases on which they are distinctive practices, and the bases for their inextricable linkage to other social processes, i.e., their unity.

The Distinctive Practice of Science

Science consists of a raw material that is our knowledge of nature. Nature consists of two distinct aspects: natural and social. Both natural and social processes contain their own phenomenal forms and real relations. But, in addition, natural and social processes do not and cannot exist in themselves. Schmidt (1971) writes:

Nature not only exists in itself, but also, and more crucially, it becomes "for us" in so far as nature is drawn into the web of human and social purposes (pp. 58-59).

The basic raw material for scientific practice is fundamental in that the transformative activity—the process of producing a particular form of knowledge—presupposes its object that is nature in the broadest sense. In a general sense, the principle activity involved in scientific practice is that of penetrating phenomenal forms of reality to comprehend the more fundamental and determinant relations. For example, in Marxist theory the sphere of production is argued to be more determinant than the sphere of exchange. Wright (1976; 1979) has demonstrated empirically the ways in which class position (defined within
the relations of production) plays a significant mediating role in the relationship between such variables as education, race and gender to income. Although it is clear that the raw material of natural science is constituted differently from social science, it is nevertheless the case that the search for explanations of natural phenomena is the basic activity of transformation. Therborn (1980:72) observes that the most characteristic feature of all great scientific achievements is the discovery of patterns of determination—laws or tendencies by which to explain natural or social phenomenal forms.

The product (outcome) of the scientific activity of transformation (i.e., penetrating an opaque reality in search of patterns of determination) is the construction and reconstruction of systematic explanations of natural and social phenomenal forms to achieve ever deeper levels of physical and social reality. One objection that is likely to be raised is that the “product” of scientific activity is not only explanation; the practice includes prediction, control and description. The response to such an objection is that only explanation is specifically the domain of scientific practice. It is true that prediction description and control are aspects of scientific practice, but if the object of the activity is other than explanation, then the activity is non-scientific. Explanation is the more basic. Prediction, control and description can follow from explanation, but the reverse cannot occur. It is, as well, the case to have prediction, control and description entirely without explanation, but these activities, by definition, are non-scientific. The product of such activities either
places them in the domain of ideology (e.g., description simply reproduces in thought the phenomenal forms) or in the domain of technology (e.g., questions of what and how, implicit to prediction and control, are basic not to the understanding of nature, but to its mastery). It is only one small step to transform the mastery of nature (technological knowledge) into an object for man (techniques and technologies).

It was mentioned above that the raw material for science is a crucial delimiting component for science as a practice. The nature of the raw material defines broadly the scientific activity—i.e., the penetration of an opaque reality. In addition, the raw material of science provides both the distinctiveness of natural science and social science and the basis for their unity. The "objects" of a natural science are distinct from those of a social science. In a social science, the object, such as "social life," may have a material base (e.g., an economic structure), but human activity, even if it is "purely" economic, necessarily includes an ideational element that provides the "agent with a conception of what he is doing and why he is doing it" (Bhaskar, 1979: 85). The objects of a social science, such as economic activity and ideology, and social and economic relations, are necessary for each other, or stated differently, they are intrinsically related to one another. The objects of a natural science, on the other hand, are strictly physical objects that stand in purely contingent external relationship, to one another. Thus, a methodology such as to be found in the Newtonian "conflict of forces" may be adequate to the task of searching for real determinations among the "objects" in the physical world, but may
be entirely inappropriate for the search and discovery of real determi-
nations in the social world. In summary, while the raw material of
science may define broadly the activity of transformation, because of
the distinctive and irreducible aspect of the raw material, natural and
social, it follows that the specific and directly applicable methods of
research may differ.

Fundamentally, the raw material of science constitutes distinc-
tions within a unity. The distinctions have been set forth to show how
the raw material of science imposes the basic conditions for the speci-
ficity of the practice demarcating it from ideological and technological
practices. But nature is also bounded by a unity of its natural and
social aspects. The unity of the social and natural is not just mater-
ial, but real domination. Besides nature producing men as "transform-
ing, consciously acting subject," men at the same become forces con-
fronting nature for their own purposes (Schmidt, 1971:61). It is on
the basis of this unity—the interpenetration of social processes with
natural processes—that science finds its connecting link to the so-
cially productive world. In an excellent discussion on Marx's concept
of nature and its relation to the social world, Schmidt (1971:98)
writes:

Society is always faced with the same laws of nature. Its
existing historical structure determines the form in which
men are subjected to these laws, their mode of operation,
their field of application, and the degree to which they
can be understood and made socially useful ... Marx con-
sidered that "man can only proceed in his production in
the same way as nature itself."
The relation between man and nature as defined by scientific practice (i.e., a thought process applied to nature towards a systematic construction of explanation) is socially mediated by the historical social structures. Thus, the concept, which is the concrete tool produced in thought by scientific practice, is historically changing while the basic laws of nature remain the same. To elucidate this relation of non-correspondence between the concept produced in thought and the real object in nature, we can turn our attention to the concept of nature itself. In an agrarian-based economy, nature was recognized as a power for itself while in an industrial economy, nature came to be recognized increasingly as an object for men. Natural processes and social processes combine to form a unity in as much as the history of nature and the history of men are mutually conditioned. Scientific practice, in the strict sense, cannot divide off natural science from social science. If the activity of transformation in scientific practice is distinguished by its search for patterns of real determination (i.e., patterns that do not exist merely in thought but rather in the real world, in nature and appropriated in thought), it becomes these very interconnections that make necessary a unity of natural and social science in order to construct a more adequate explanation of the natural phenomenon not in itself, but rather for man.

Now that the scientific practice has been explicated in its specificity, together with the basis for its inextricable link to social processes, let us turn to its relation to other practices, in particular ideological and technological ones.
Ideological Practice

Ideological practice is the "process of producing lived experiences of social relations through the transformation of individual encounters with social relations as raw materials" (discussion with Erik Wright). Two key points can be taken from the constituents of ideological practice that will shed light on its relation to other practices. First, the raw material, social relations, is the material element that pervades all other practices. Second the practice involves an activity of transforming objective processes into subjective ones (see Althusser, 1971 on "interpellation"). Because human beings are not mechanical robots, but rather conscious actors--i.e., human subjects--there is again a basis for unity of ideological practice with all other practices.

Strictly speaking, ideology does not constitute a practice in the same sense as do other practices. Ideology is not something people do as with scientific or technological practices. This being the case, the two points mentioned above provide the basis for understanding ideology more precisely as an ubiquitous dimension of other practices. Since the immediate and concrete social relations (in contrast to, let us say, the abstract, fundamental structure of social relations reflected in the Capitalist Mode of Production) vary across the other practices, it is more useful to see different ideologies associated with different practices (Bhaskar, 1979:85).

Taken in the above sense, ideology is not something science eliminates. The raw material of science is nature in all of its inner
connections and phenomenal forms. Ideology, as we have defined it, is seen to mediate the transformative activity of science. Scientific practice is embedded in social relations while working on phenomenal forms to appropriate real determinations. Ideology is an inescapable companion of scientific practice, inviting itself into the practice through social relations and expressing itself in the subjective motives and meanings of the scientists. In this way ideology mediates the very process of the production of scientific knowledge: the questions determined to be significant, the method of inquiry and the interpretation.

But, ideology has a material base (social relations) that is dynamic. Given an underlying dynamism of the raw material—the objective processes that call forth (interpellate) subjective meaning—it follows that ideology (i.e., the product of the process of transformation) can never be uniform and fixed, but rather is always inconsistent and in competition with other ideologies. By virtue of the nature of its material base, ideology can never be entirely functional—to the contrary, it can only be to a greater or lesser extent contradictory depending on the constitution of its material base.

Now, if it can be accepted that ideology is a contradictory process and as well an inescapable companion of scientific practice, mediating the very transformative activity, then it follows that ideology plays a necessary role in the determination of the field of scientific practice—the limits of variation in scientific practice. At the risk of gross over-simplification, it may be stated that a socialist ideology
would allow for certain forms of scientific activity that would build a unity between natural and social sciences which, under a bourgeois ideology, could not be possible. Does this mean that science is reducible to ideology? This is not at all the case for at least two important reasons. Unless scientific practice contained within it a possible form that was, in our example, the unity of natural and social sciences, an alternative ideology could not realize it. In other words, ideology cannot realize something in scientific practice that does not already exist. Second, in the process of scientific practice itself one could expect a reciprocal effect on ideology. If, in the process of knowledge production, the phenomenal forms are found to have a different explanation than otherwise assumed, that realization will have an effect on the ideology that had originally reproduced those phenomenal forms in thought.

It was necessary to conceptualize science as a practice because, as this chapter has attempted to point out, "practice" is the concept that functions most satisfactorily within a theory anchored in the primacy of the relations of production. Although science operates in an institutional setting, to begin to view science in its institutional context excludes a priori the mechanisms by which science was shaped. Similarly, science is not a productive force. Cohen (1978) correctly qualifies this statement by saying that only productively useful scientific knowledge can be included among the productive forces. But even then, the product, scientifically useful knowledge, presupposes a material base, such as nature, that is anchored in social relations.
Thus, although it is correct to see scientifically productive knowledge as a productive force, it is as well, and more fundamentally, the outcome of a certain activity embedded in a structure of social relations and carried on in order to appropriate the real relations of nature in thought. The "outcome" is a determined outcome that can be reduced neither to a physical object or thing, nor to social relations apart from their material base.

The Distinctive Practice of Technology

There are at least two salient ways in which our discussion on science as a practice has a bearing on the conceptualization of technology. First, for the same reason that the notion of science was transformed in order to be fitted into the structure of social relations and to become a specific site of struggle, so also, and in a similar manner, must our notion of technology be transformed. Secondly, while science and technology are both practices, technology has its own activity and raw material and therefore its own specific bases for interconnection with other social processes that are separated from scientific practice.

Like scientific practice, technological practice has for its raw material nature. Technological practice differs from scientific practice mainly in its activity of transformation of that raw material and in its product. The distinctive feature of the technological activity is its drive for the mastery and control of nature to serve the purposes of man. This distinguishing feature of technological activity
contains some pivotal points at which to establish the specificity of technological practice as a site of struggle and its interconnections with other social processes.

First, the drive for the mastery and control of nature is distinct from a drive to understand nature. Simply put, the pursuit of "why" questions presuppose a different kind of activity than do "how" and "what" questions. This certainly means that scientific activity can feed into technological activity to the extent that solutions to "why" questions lead to solutions for "how" and "what" questions. Scientific activity thus can and does exist alongside and enmeshed in technological activity, but this does not mean that technology has become a scientific practice or vice versa. By definition, technological practice is more bound up in other social processes than is scientific practice because it is through technological practice that the purposes of man are directly served.

Second, man as an intentional being becomes the connecting link between the object in nature and the instrument of labor (Schmidt, 1971). Leiss (1977) draws a distinction between technique and technology in order to underlie the social process behind the production of technologies. He defines technique as:

solutions to practical or theoretical problems arising out of the environmental forces that impinge upon organisms (p. 118).

Technologies are:

combinations of techniques and the combinations represent choices among alternative uses or goals in the service of which the techniques are applied (Leiss, 1977; 120).
The location of technique and technology in the social structure is described below (Leiss, 1977:129): 

(Techniques) set out a solution for a problem involving the relationship between means and ends and it is a matter of indifference, so far as the technique itself is concerned, who performs the relevant operations and under what conditions. So far as a society or culture is concerned, however, this is not at all a matter of indifference. In established social patterns, techniques are almost always combined with class, status, and role determinations that specify who can perform the operations associated with techniques ... This combination is what I call a technology ...

Leiss' distinction leads to a view that "techniques" are the outcome of a "private" activity or individual activity which in turn is subjected to and molded by social influences to produce a technology which represents a particular combination of those techniques. This view assigns to technique an overly neutral character since in actuality techniques and technologies are generated simultaneously within a social context. The division between the private and cultural is false. Likewise, technology is constructed in such a way that its nature carries with it a social imperative. Although Leiss is pointing in the correct direction by conceptualizing technology in a way that brings into view human purpose and the choices that lie behind a given technology, there is a marked void in bringing this notion one step further by conceptualizing technology as a practice and therefore a specific site of struggle. In this latter sense, the social imperative and the extent of "randomness" in the creation of techniques are not pre-given, but rather are determined by the outcome of struggle within certain structural limits that signal in what capacity technological practice will serve competing and contradictory interests.
Others (e.g., Noble, 1977) remain similarly vague on the specific nature of technology and fail to see the field of activity that we speak of as technology as a site of struggle. Noble (1977:4) sees only the functional side of science and technology while underplaying the contradictory side:

From the start modern technology was nothing more nor less than the transformation of science into a means of capital accumulation, through the application of discoveries in physics and chemistry to the processes of commodity production.

The urgency to view technology as a site of struggle constituted by a certain kind of purposive action leads us to the third point in elaboration of technology as a specific practice linked to other social processes.

Thus, thirdly, technological practice has its own specificity via the range of human choices and the social-material base that it implies. It is the social-material base, together with the alternative arrangements of nature, that give rise to a range of choices within which, through struggle, some options are selected over others. Figure 5.1 below shows what might be considered the logical pattern of technology as a practice.

Although the components of technological practice shown in Figure 5.1 represent a close-knit circular pattern within which there is no empirical "starting point," for purposes of presentation we begin with knowledge of alternative arrangements of nature. The alternative arrangements of nature are the outcome of the existing level of scientific
and technological development confronting a fixed and unchanging nature. Scientific practice contributes to the breadth of possible arrangements of nature. The principle site of technological practice is the social-material base constituted by relations between men and between men and the instruments of labor. The structure of this social-material connection signals a range of human choices or interests, or needs that are acted on at a site of struggle determined by the social-material connection. Together, the range of human choices and its field of choosing—i.e., the site of struggle—give way to the phenomenal forms, such as technological knowledge (i.e., knowledge of how and what to do), concrete technical objects (i.e., instruments of labor) and socio-technical arrangements (i.e., particular educational techniques, strategies for extension, etc.)
It is important at this point to set forth several decisive observations about the phenomenal forms that are relevant in the context of this dissertation. First, in Figure 5.1, concrete technologies are referred to as "phenomenal forms" because they appear to the worker and capitalist alike (in greater or lesser degrees) as an indifferent but useful package of nuts and bolts. Moreover, when inserted into the social-material base, they inevitably promote an ideational element, i.e., they contribute to ideological practice as a component of the raw material for transforming objective processes into subjective ones. Second, it follows from the first observation (but not so clearly evidenced in the figure) that the phenomenal forms themselves—drawn into the material-social base—condition the range of human choices and future technological changes. Thus, we are in agreement with Burawoy (1978) when he suggests that interests are not at the same level of the basic structure which denotes real relations and are simply derived from them. Rather, they are produced and reproduced in particular ways within a social-material base that has, with greater or lesser success, constructed phenomenal forms that intercept the real relations. Thirdly, the phenomenal forms are an "outcome" or a product of technological practice inseparably linked to its conditions of production: a social-material base, a range of human choices and a site of struggle. Fourthly, we can see from the figure that the phenomenal forms produced in technological practice are multi-dimensional. This dissertation is primarily
interested in the creation and development of technical knowledge and its use together with the concrete instruments of labor that accompany that knowledge.

For the Capitalist Mode of Production, the classical social-material connection is found in industrial production enterprises where capitalists, workers and the instruments of labor combine in particular ways for the production and appropriation of value. Burawoy (1978:260) identifies the "formal" aspect of this social-material connection and distinguishes it from the social organization of production under a feudal system: (1) there is no separation in time or space between necessary and surplus labor time; (2) laborers are never in possession of the means of subsistence during the production process; (3) laborers cannot set the means of production into motion by themselves; (4) the amount of surplus cannot be specified ahead of time; (5) laborers are compelled to go to work through the very need for survival rather than through extra-economic mechanisms.

This social-material connection in regards to technical change defines in a fundamental way the range of choices and the site of struggle. As Marx correctly pointed out, there are two ways of increasing the surplus value of the worker (i.e., that value above the historically determined minimum level of subsistence): lengthen the working day or increase the workers' rate of productivity. Given the absolute limit to the length of the working day, reorganizations of the production process (such as speed-ups), more effective managerial
skills and technical change, all contribute to the securing and obscuring of surplus value. They are what Burawoy (1978) refers to as the relations in production that reproduce the relations of production. Burawoy (1978) and Noble (1978) argue that technical change is driven by a two-fold force: efficiency and control. By Burawoy's (1978) conceptualization of relations in production, which includes the instruments of production, he is able to show how technology is itself an object of struggle between classes and, hence, an object to be used in furthering control over the production process as well as (and in addition to) increasing efficiency in order to improve one's competitive position among other capitalists.

The social-material base defines as well the site of struggle. In the classical form described above where workers are without control of their means of production and must sell their labor power to capitalists and subsequently that labor power must be realized for the production of surplus value, struggles ensue over the control of that production process. Some level of capitalist control is the necessary condition for the securing of surplus value. Given the social organization of production, struggles occur on the shop floor in negotiations between management and labor. In either case, the struggles are characterized by a direct confrontation between capitalists and workers.

Where the social-material base changes, one can also expect shifts in the range of choices and in the site of struggle. The particular object of study at hand is the agricultural sector, where the
producers themselves in large measure retain possession of their means of production and, therefore, seemingly retain control over technical change. There are no capitalists that they confront directly and who place increasing demands for efficiency and control over the labor process. There are no "shop floor" struggles or labor management negotiations. In the context of the agricultural sector, the central concept of control as employed by Burawoy is no longer useful because the social-material base is different. Does this mean that for agriculture technological change is purely a function of increasing efficiency and hence, the technologies do not come to bear on the actual relations in production? If they do not come to bear on the relations in production, i.e., function to reproduce the prevailing relations of production, then they are, unlike industrial technologies, neutral. Of course, the position of this dissertation is that the technologies developed and employed in agriculture are not at all neutral; only the concept of control and the site of struggle are different.

Burawoy (1978) points out that control assumes an entirely different meaning in the context of capitalist relations than in the context of feudal relations. Similarly, one could expect "control" to assume another set of parameters when relating subordinate non-capitalist relations to the dominant capitalist relations. Much has been written on the articulation between modes of production and/or their interpenetration (Foster-Carter, 1976; Wright, 1979; Roseberry, 1978; Wolpe, 1980). Poulantzas (1978) refers to the subordinate non-capitalist
relations as conditions of existence for the dominant capitalist rela-
tions. We may take this notion one step further by suggesting that in
the context of a large part of the agricultural sector related to the
non-agricultural advanced capitalist sector "control" can be understood
as the process of securing those conditions of existence. "Control" in
this sense, as in the other two senses, involves the production and ap-
propriation of value, but within the context where to a large extent
the producers are in possession of their means of production. Posses-
sion of the means of production, at least in a formal sense, constrains
the possible ways that the more dominant capitalist enterprises can direct
and organize the production process in agriculture. Thus, Taylorism
and other management techniques are uncharacteristic of the agricul-
tural sector and unheard of for petty commodity production in the formal
sense. A principle avenue remaining for the dominant capitalist rela-
tions is to secure their conditions of existence through technical
change (revolutionizing the instruments of labor) and a supportive so-
cial system (such as extension and other education programs) to diffuse
those technologies.

Due to the particular structural relations implied by the rela-
tion of capitalist with non-capitalist relations of production (i.e.,
a social-material base distinct from the classic form within capitalist
relations), not only does the notion of control change, but the site of
struggle is changed as well. Except for uncharacteristic, fully capi-
talist farms, the site of struggle is not in the "fields" as on the
shop floor, nor do negotiations occur in a farmer's house, as between labor and management in meeting halls. Instead, the site of struggle is embodied in large measure within the state and made effective through its power (e.g., establishing policy) and through its apparati (e.g., in the present case, technological research organizations). If we are to examine technical change in agriculture—its extent and form—a crucial site of struggle is in the research institution. The research institution—its myriad efforts at developing technologies—mirrors the contradictory forces constituting the social reproduction process and can serve as an important gauge for capturing the extent and form of technical change in agriculture. But our aim is not so much to draw inferences about technical change in agriculture for Brazil from what occurs in a single research organization, but rather to show the ways in which some fundamental structural processes give shape to the direction and aims of the research institute. Certainly, the institute is not a site of struggle in the same sense that conflicting social groups are inside the organization fighting for their own specific technologies. Appearances are not altogether identical with the fuller reality. The efforts of the research organization that appear automatic are in fact the product of a decision-making process already determined by a state that is given its fundamental shape by the accumulation process and the prevailing balance of class forces.

The major focus of this study is one aspect of technological change in the agricultural sector—the creation of new agricultural
technologies, together with its structural determinants. Future study could include the determination of the supportive social system as well. Since technology is treated as a practice constituted by integrated components such as a raw material, transformative activity and a product, we can have some indication of the nature of this practice, i.e., its underlying dimension of control, by examining its product—the ways in which the product manifests control and hence contributes to the securing of the conditions of existence in the agricultural sector. Of course, technologies do not always have their intended consequences. "In actuality, the impacts are always determined subsequent to the introduction of the technology and in ways not altogether consistent with the intentions of the designers" (Noble, 1978:320). Nevertheless, the social reproduction process gives to technical change a certain shape that is reflected in the demands of accumulation and in the balance of class forces in the state. Technological change serves certain ends determined by the social-material base, and these ends, like the technologies themselves, are always to a greater or lesser extent problematic. The qualitative nature of technologies, then, can only be understood by examining the social-material base from which it is generated (via the range of choices and struggle) and in what capacity (contradictory/functional) it serves in the social reproduction process (i.e., the on-going creation and appropriation of surplus value).

Thus, our view of technology cannot be a mere quantitative one, because before technology has a quantitative aspect (i.e., certain levels
of technology), it has a qualitative aspect which is a certain form(s) determined by the social reproduction process. It is only within these structurally determined forms that it is then possible to speak of the level or extent of technology. In short, in conceptualizing technology as a practice it is possible to examine the determinate and varied forms of the technology, the conditions under which one form prevails over another, and its functional/non-functional role in the social reproduction process. This essentially structurally limiting and selection process presupposes and underpins the quantitative dimension of the technology by allowing for the intensive expansion of some technologies while constraining others.

Viewing technology as a practice embedded in social relations of production gives to the study of technology a ring that is altogether different from viewing technology as the throttle of efficiency. Efficiency abstracted from social relations leads to the kind of inevitability of a non-distinct technology that Bell (1973:354-355) upholds:

The technocratic mode has become established because it is the mode of efficiency—of production, of program, of "getting things done." For these reasons, the technocratic mode is bound to spread in our society.

The concept of technology as a practice, on the other hand, provides a basis for drawing the connection between technology and the underlying social reality in such a manner that technology is neither reducible to the social relations nor raised up to an absolute symbol of progress. "Technology" in its phenomenal forms presupposes a raw material (nature), a social-material base (e.g., capitalist relations),
a range of human choices embedded in that base and a site of struggle (e.g., the shop floor). The questions for which this concept of technology prepares us to find a solution are: in what capacity does technology serve the social reproduction process? and, equally important, what is the precarious nature of this capacity? That is, what are specifiable structural conditions for the possibility of a given technological form and the limits to that possibility?

It was mentioned previously that there are several types of phenomenal forms of technology such as: purely technical (e.g., instruments of labor) together with the mental side of that technology (how to construct the instrument and how to use the instrument); and purely social (e.g., extension programs) together with its mental side. Because our focus is on a research organization, the salient aspect of technology in this study is the mental side of the purely technical phenomenal form—in particular, what may be referred to as agricultural research technology.

For a fuller understanding of the process studied in this work (the process of creation in agricultural research technology), further conceptual distinctions need to be made along the lines of the mental aspect of the phenomenal form in technology. One of these is that between agricultural research and agricultural research technology. Agricultural research does not produce technology, only the potential for it. It is not a "thing" made to fit into the agricultural setting. Rather, agricultural research is a specific practice within agricultural
sciences. With this practice a specific raw material (our knowledge of agricultural nature) is transformed into a new product (new knowledge about the agricultural nature). In this sense, the realization of agricultural research finds its way in at least two directions: one is toward an increase of our knowledge of nature in agricultural science (say "pure" science), and another is toward linking the laws of nature with social practice (say "applied" science). Attempts to conceptualize agricultural research as an activity that utilizes scientific knowledge to solve technical and practical problems in agriculture (e.g., Aldrich, 1966) is, at best, unclear and, at worst, confounding. Agricultural research is a scientific activity and not a technological one. The product (outcome) of the agricultural research is not only explanation about agricultural nature, but also prediction, control and description. In this context, a major distinction needs to be made: that between agricultural research (scientific practice) and agricultural research technology (technological practice). Agricultural research is directed to understanding agricultural nature. Agricultural research technology is directed to control agricultural nature (remember that nature has two aspects, natural and social). In fact, agricultural research can feed into agricultural research technology. It was argued above that solutions to "why" questions lead to solutions to "how" and "what" questions. But, in spite of the close relationship between the two practices, they continue to be different. Agricultural research technology is a practice which transforms a raw material (nature) into
an output (agricultural technology). It is a practice intending to master and to control agricultural nature to serve the purposes of man. This practice, thus, is not neutral at all. Rather, it constitutes a site of struggle where different interests confront each other in an asymmetrical manner. Agricultural research technology is that area of research concentrated in producing, developing and adapting technology to agriculture. It is also a specific form of intellectual labor. In capitalist societies, this form of intellectual labor (agricultural research technology) has a strong tendency to both legitimate power and to exhibit an organic relation with the political relations of domination (more on this later in this chapter).

In a study on cereal grain producing areas, Evenson (1974) distinguishes two types of research activity: agronomic and plant breeding research on A-type and related agricultural science research on S-type. The A-type research was measured by scientific publications on the five cereal grains classified by Plant Breeding Abstracts (i.e., wheat, barley, maize, sorghum and rice), and the S-type research was measured by scientific publications on plant physiology, phytopathology and soil science abstracted in Biological Abstracts. This distinction, which has been used and discussed in other studies (Evenson and Kislev, 1975; Boyce and Evenson, 1975; Evenson, 1978), has revealed some interesting empirical research findings. It was verified, for example, that an investment in A-type research (which, in the terminology of this work, involves agricultural research and agricultural research technology
together) in time t does not produce discoveries actually used by producers until two to three years after investment (see Figure 5.2).

![Diagram of Annual Benefits Stream]

Figure 5.2. Timing of research contributions (from Evenson, 1974:7; Boyce and Evenson, 1975:102; Evenson, 1977:249; Evenson, 1978:64)

The expected production reaches its maximum point (M dollars) eight to ten years after investment. After this period of time the gains begin to depreciate due to facts such as "erosion of crop yielding ability by new disease organisms and pests" (Boyce and Evenson, 1975:103).

Another interesting finding is represented in Figure 5.3. It shows the interrelationship between agricultural research (A-type) and related agricultural science research (S-type). The close association found by Noble (1977) between science and modern industrial technology is with Evenson (1978) replicated in the agricultural setting between related agricultural science research and agricultural research (agricultural research technology included). Investments in related sciences
have been revealed to be extremely important in terms of actual increases in gains within farms. These investments assure not only higher annual benefits in terms of gains but a longer period of maximum returns over time as well. The investment in related agricultural science research, i.e., groundwork research, is basic to the creation of a potential for developing agricultural research and agricultural research technology. However, at least two points need to be stressed. One is that agricultural technology is not exclusively science-based. There is technology that results from labor in action as well. The other point is that one cannot minimize or hide the importance of the feedback that agricultural research and agricultural research technology have in relation to the
related agricultural science research. Among the important aspects of Evenson's (1978) findings highlighted in Figures 5.2 and 5.3 is that of pointing out the role of the related sciences to the actual process of creation of agricultural research technology.

Agricultural technology, like any other form of technology, does not have an inner autonomous dynamic which directs social change under its laws of functioning. To assume some form of inner logic or dynamic in agricultural technology, placing emphasis only on the adaptability of the agricultural technology to some specific environmental setting, is to concur with one of the most widespread interpretations: technological determinism. Such an interpretation "sees" technology as the major force in the process of social change. Implicitly or explicitly, this kind of determinism is present in a great majority of the studies which focus on the relation between technology and society (Galbraith, 1978; Bell, 1960). The understanding of the relationship between agricultural research technology and its output (a specific agricultural technology) depends on an analysis which focuses on the articulation between social reality and agricultural research technology—that is, an analysis which identifies those social mechanisms that, in several forms of determination, shape the process of creation of agricultural research technology. Figure 5.4 tries to put together parts of a larger set of interrelationships involving the creation of agricultural research technology.
Figure 5.4. Three Conceptually Different Moments in the Construction of a New Agricultural Technology.
The pre-production phase (or Moment 1) is formed by those elements which shape the process of production of agricultural technology and which also shape the post-production (Moment 3), i.e., the actual agricultural technology formed by machines, tools, recommendations, together with their technical imperatives.\(^{13}\) The elements placed in the pre-production Moment permeate all the other moments, i.e., they do not disappear after exerting their differential influence. On the contrary, they remain shaping and simultaneously being shaped by the other conceptual-theoretical moments. The merit of Figure 5.4 is in identifying and putting together these different moments or phases. However, the structural articulation within and among these different moments is more visible in Figure 5.5, where the links of the elements (or variables) are viewed through a schematic representation which shows the complex interconnections of several modes of determination.

Figure 5.5 shows that the process of creation of agricultural technology is transformed by the knowledge produced by related sciences, agricultural research and agricultural research technology as well. This set of knowledge is at the same time "limited" by the forms of capital accumulation and "selected" by the state (mainly through state policies). When it emerges, the agricultural technology is the concrete result of many determinations. This means that its shape is not an exclusive determination of a "pure" scientific activity, but the result of a differentiated determination where the forms of accumulation of capital and the state policies play one of the major and direct roles. For
Figure 5.5. Model of Determination Combining Selected Elements of the Pre-Production Phase of Agricultural Technology with the Process of Production and its Post-Product
example, when it was said above that agricultural research technology is a specific form of intellectual labor which tends to legitimate power and to exhibit an organic relation with the political relations of domination, this did not mean that the researchers intentionally set their research agenda to serve the interest of capital. Rather, this meant that different structural modes of determination set the terrain for the scientific and technological work, shaping it through mechanisms of limitation, selection, mediation, transformation, etc. The word tendency present in the sentence tries to depict the structural character of the situation in which the scientific activity occurs. If there are tendencies, there are also counter-tendencies, such as the character of class practices. The structural character of the situation does not transform itself; it is transformed as an effect of class practices. Intending to clarify the relationships among the different elements closer to the process of creation of agricultural research technology, Figure 5.5 does not assume the total complexity that it should. This is the only justifiable reason for the absence of class practices in the model of determination shown in Figure 5.5. However, it needs to be clear that class practices do not only transform the forms of capital accumulation and the articulation of forces and relations of production, but they select the state policies and state interventions as well. Inevitably, a more complex model of determination would incorporate class practice together with its fundamental determinations.14/
Another aspect which Figure 5.5 reveals is the character of reproduction/nonreproduction assumed by agricultural technology with relation to the forms of capital accumulation and state policies. Forces of production not only reproduce the relations of production, but at the same time they conceal the essence of those relations of production (confusing the difference between necessary and surplus labor) which means that (empirically) this character of reproduction/nonreproduction is not easily identified. Concretely, this means that the production and introduction of new technologies have been the basis for a new ideology: the presentation and increase of capitalist relations as an exclusive technical problem, without any political concern (Marcuse, 1965:1-18, 144-169; Habermas, 1970:81-122; Burawoy, 1978:253-281). The tendency of "forces" and "relations" to obscure and secure the forms of production and appropriation of surplus value makes the task of analyzing agricultural technology, in what capacity it serves in the social reproduction process and its process of creation much more difficult.  

Two problems arise in applying the theoretical term agricultural research technology to empirical study. The first is a problem of measurement. Agricultural research technology does not reflect any readily observable entity. Instead, it is a concept that must be inferred from a pool of activities and outcomes related to agricultural technology. As an inferred variable, agricultural research technology can be measured according to different indices, but whichever index is used cannot be a complete measure of the attributes that comprise the concept. The
second problem arises not from measurement per se, but rather from the kind of concept that agricultural research technology is. The concept as we use it has two aspects: qualitative and quantitative. Agricultural research technology is quantifiable due to its thing-like character. Still, agricultural research technology is the outcome of class forces as well, and hence takes on various specifiable forms. "Forms," postulated to arise from antagonistic social relations, are therefore differentiable on the basis of their class character. Measurement of agricultural research technology thus involves a two-fold concern: deriving indices from an inferred variable and differentiating "forms" of technology on the basis of their class character.

Due to the close relations between agricultural sciences (applied sciences) and agricultural research technology, the productivity of the process of creation of agricultural research technology has been measured in terms of publications (Evenson and Kislev, 1975:29; Evenson, 1974). The number of publications in agricultural sciences says nothing about the kind of research which is published. If, after a certain reasonable amount of investment in research, no publications are visible, this is an important sign that something wrong is going on in research. But, if a large number of publications show up after the investment with a negligible level of excellence, this also is an indicator of problems in research. Unfortunately, the measurement of productivity in the process of creation of agricultural research technology based on publications hides this latter possibility. The major criticisms that have
been made of Evenson and Kislev (1975) have concentrated not on this side of the shortcomings (i.e., measurement of the productivity of the research system in terms of publications), but mainly—what is also important—on the methodology for estimating the economic productivity (economic returns) from agricultural research (e.g., Hertford and Schmitz, 1977; Lindner and Jarrett, 1978). The empirico-analytical treatment of the process of creation of agricultural research technology is carried out in the next chapter (Chapter 6).
1/ We do not mean to suggest here that technology has no determining impact on social reality. Many studies have shown the good and bad consequences of technology on society (Bell, 1960; Perelman, 1977). Indeed, it is by virtue of technology's impact on society that it becomes more crucial to study the social determination of our technologies and hence, begin to build the conditions for where a more consciously directed development of technologies is possible.

2/ Chapter 3 provides a more thorough discussion on the use and formation of concepts.

3/ There has been a deliberate attempt to avoid demarcating the Marxist literature on the nature and role of science and technology according to the popularized notion of Chinese model vs. Soviet model. Underpinning each model are substantive theoretical discourses which are precisely what are necessary to confront head on if we are to go beyond the unsatisfactory positions given to us.

4/ It should be noted that not all theorists defending the primacy of the productive forces deal with science as any other productive force Cohen (1978:46) shows that science is a mental activity that, although distinct from ideology, "may contain ideological elements, but it is despite them that it is science, and despite them that it is productively useful and so a productive force."

5/ Bhaskar (1978:ch. 1) refers to the transitive aspect (i.e., concept) and intransitive aspect (the real object in nature) of knowledge. The transitive object of knowledge includes "the antecedently established facts and theories, paradigms and models, methods and techniques of inquiry available to a particular scientific school or worker." The intransitive object of knowledge does not depend upon human activity at all. These intransitive objects are, for example, "the specific gravity of mercury, the process of electrolysis, the mechanism of light propagation" (Bhaskar, 1978:21).

6/ Althusser (1971:174) labelled this process of transforming objective processes into subjective ones interpellation and describes it:

   Ideology "acts" or "functions" in such a way that it recruits subjects among the individuals (it recruits them all) or transforms the individuals into subjects (it transforms them all) by that very precise operation I have called interpellation.
Science is conceived of as a practice that is distinct from ideological and technological practices. As a practice science cannot be an institution. A university, for example, is an institution. Science, ideology and technology are practices that may occur within an institution. Institutions are the concrete and immediate social forms that give shape and direction to the practices that occur within them, but they do not subsume the practices. Science, an absolute dimension of human activity, as are other practices, remains the site of struggle to be adapted and molded according to the relative strength and opposing forces in society.

Noble is certainly not blind to the contradictory nature of science and technology as evidenced in several passages to be found in this book. Nevertheless, he does not incorporate these casual comments of theoretical importance into his actual analysis.

There are of course, other sites of struggle such as between extension agents and potential adopters. Another site of struggle is in the field and in negotiation between farm workers and farm owners paralleling the industrial setting. This of course, presupposes a social-material base of the classic CMP where the farm worker is not in possession of his means of production and the owners intervene directly to organize the work process in the interests of capital. See Friedland (1980) for the study of this dimension of the social determinants of technology located squarely within the labor process itself.

The view of technology as a practice is here being offered as an alternative to two deeply unsatisfactory views: one view that sees technology as purely an adjunct of capitalist relations and, hence, to be "eliminated" in the process of transforming those relations; and another view that equates technology indiscriminantly with progress. Implicit to our discussion of technology as a practice is a distinctive method: a way of forming the concept and using it that is to be distinguished from the two unsatisfactory views mentioned above. This method, referred to as the realist approach, was discussed in greater detail in Chapter 3. In short, the argument that is laid out is that the realist approach side steps speculation (ideas set up over and against reality) and empiricism (exclusive focus on phenomenal forms) to appropriate the real determinations of social reality.

The output of science is usually classified into two broad spheres. The theoretical-methodological output is classified as the outcome of pure science and the practical output is classified as the outcome of applied science. Thus, "pure" and "applied" sciences appear
as distinct but related domains. "Pure" science appears to know a part of Nature and "applied" science, based on the scientific knowledge available, appears as wishing to control Nature. This division of science has become more "officialized" when some governmental agencies trying to operationalize the use of the distinction began to develop a definitional map to be used in reporting funds for scientific research and development. Among these agencies is the National Science Foundation (NSF). From the National Science Foundation comes, in 1958, a set of definitions of terms and, among them, the distinctions between research, basic research, applied research and development. Research is understood as

systematic, intensive study directed toward fuller scientific knowledge of the subject studied. It includes both basic research ... and applied research which is directed toward practical application of science (NSF, 1958:75).

Basic research is understood as

that type of research which is directed toward increase of knowledge in science. It is research where the primary aim of the investigator is a fuller knowledge or understanding of the subject under study, rather than, as in the case with applied research, a practical application thereof (NSF, 1958:75).

On the other side, development is understood as

the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems, or methods, including design and development of prototypes and processes. It excludes quality control or routine product testing (NSF, 1958:75).

If the distinction "pure" and "applied" science is to persist, the content of the NSF's (195) definitions deserve closer attention. It needs to be clear that in pure research the "fuller knowledge or understanding of the subject under study" must include not only the natural phenomena taken in pure form but also their interpretation in social practice (Nikolayev, 1975:24). It needs also to be taken into consideration that this research directed "toward increase of knowledge in science" has social, political and economic consequences. Evenson (1974:1) makes the important observation that "it is not true that discoveries which are in the form of abstract concepts or knowledge lack economic value." He argues:

Improvements in experimental design, improved scientific equipment, expanded stocks of genetic materials, more reliable estimates of heritability, and advances in the
understanding of physiological characteristics of plants, for example, have obvious impacts on plant breeding and agronomy (Evenson, 1974:2).

In effect, Evenson and Kislev (1975) and Boyce and Evenson (1975) demonstrate some empirical validation to the connection between efficiency in agriculture and scientific research. On the other hand, the direction "toward practical application of science" characteristic of applied science needs to encompass the concern for linking the laws of nature and society with social practice (Nikolayev, 1975:24).

12/ Evenson is all the time measuring productivity of agricultural research by number of publications (refer to Boyce and Evenson, 1975; and Evenson and Kislev, 1975). As Erik Wright pointed out in conversation, this measurement can lead to misleading conclusions. He called attention, for example, to the fact that, at least in social sciences, investment in research can signify no advance in knowledge and at the same time an increase in number of publications.

13/ Technical imperatives or technical rationality is a mode of purposive rational action that accompanies the implementation and use of a given technology (Fleron, 1977:3-4; Burawoy, 1978:293; Leiss, 1972:199; Marcuse, 1964:xv, xvi, 144-169; Giddens, 1971:215-216; Schroyer, 1973). The fact is that technology is intrinsically linked with social reality, bringing congealed with it a form of social labor. It needs to be observed that the technical imperatives "may take the negative form of ruling out rather than specifying certain features of the relations in production" (Burawoy, 1978:291).

14/ For a discussion on class relations in agriculture for advanced countries, see Singer (1979) and Mooney (1979). For a quantitative treatment of the Marxist concept of class mediating income inequality in capitalist society, see Wright (1976, 1979).

15/ This tendency of "forces" and "relations" to obscure and secure the appropriation of surplus value is extensively discussed in Burawoy (1978).
ACCUMULATION OF CAPITAL AND AGRICULTURAL RESEARCH TECHNOLOGY

The basic objective of this chapter is to empirically and theoretically explore the relationship between accumulation of capital and the creation of agricultural research technology. These two levels of analysis (theoretical and empirical) constitute an important unity. In this chapter, the movement of the analysis goes back and forth between the theoretical and the empirical realms. Chapters 3, 4 and 5 provided the new terrain of work. As a unified set, they form the theoretical-methodological background for our strategies of investigation and arguments.

In this chapter the association between accumulation and agricultural research technology is investigated through the analysis of some of the major events in EMBRAPA during the period 1974 to 1979. The critical discussion of the "functionality of agriculture" thesis gives the basic lines of interpretation on the available quantitative and qualitative data and, thus, the parameters for an evaluation of Hypothesis 4.1.

The importance of this discussion is to offer a point of entry into the data analysis to see if there is a pattern in the data that is consistent with our theory. It does not follow, however, that our
theory is the only one that would be consistent with the data presented. As our discussion in Chapter 2 stressed, other theoretical orientations have pointed out "elements" of the agricultural research process which enhance our understanding. Moreover, for non-experimental research designs (such as this study) the inconclusiveness of empirical findings is virtually an inescapable condition. What is to come is a first attempt to explain the pattern of empirical phenomena. The point of our analysis here is to enrich previous understanding and explanatory power of the agricultural research process. In this sense, "our knowledge effectually enables us to attain reality, although without even being able to exhaust it."  

Accumulation and the Restructuring of the Brazilian Research System

Some have argued that historically in Brazil, noncapitalist agriculture, with its traditional techniques, has been functional to the overall capitalist accumulation process (see, for example, Dias, 1978; Martins, 1975; Paiva, 1968, 1971, 1973, 1974; Castro, 1969). This functionality has set the conditions of existence for the reproduction of capital through the structure of prices that assures the rapid increase of the rate of profit primarily in industry. At the same time, the continuity of these relative prices reproduces the pre-capitalist relations in agriculture. However, as Silva (1977) stresses, this functionality has never been a solution to the contradiction that emerges in the capitalist accumulation process. The contradiction resides in the fact that capitalist development brings with
it the development of capitalist relations in agricultural production itself, creating a tendency to obstruct (tendency to produce crisis) the movement of the dominant forms of accumulation.

Capitalist penetration reproduces social relations in the agricultural sector in accordance with its overall level and pace of accumulation, but there is no necessity for this process of reproduction to be functionally compatible. In fact, capitalist penetration in agriculture undermines the very conditions that previously sustained accumulation (such as cheap food to urban workers). New conditions must be established for accumulation to push forward. The form that agricultural research technology takes is an aspect of these new conditions which various groups within and outside agriculture are struggling to establish.

The thesis of the functionality of agriculture to capitalist accumulation in Brazil has the potential of missing the essential point: the analysis of the contradictions that emerge with the production/reproduction of the conditions of existence which will continue the viability of the accumulation process. Insofar as the non-capitalist forms of production are reproduced in the process of accumulation they become a part (functional and contradictory) of overall accumulation in Brazil (see Silva, 1976 for an excellent critique of the "functionality of agriculture" thesis).

Ideally, our evaluation of EMBRAPA (which was only formed in 1974) and the period of analysis for this dissertation should cover a longer time span. This problem aside, the point here is to relate
the events in EMBRAPA during this period (in particular, its allocation of resources and priorities of research) to the overall interest of capital which, as already pointed out, is at the heart of accumulation. In other words, the process of production of agricultural technology cannot be explained only by individual creativity nor through the internal operations of an organization. Structural constraints and limitations are operating to rule out technological events and, at the same time, to make others more likely.

In a dependent social formation such as Brazil, not only the forms assumed by capital but its laws of motion (when compared with those of "core" countries) have their own specificity. In his studies on Brazilian agriculture, Martins (1969, 1969a, 1972, 1973) has offered an important contribution in spelling out the specificity of the development of capital in Brazil. The position which is defended here is that capitalist accumulation in Brazil explains the nature of the agricultural technology which is produced and/or adapted by an organization such as EMBRAPA. EMBRAPA itself is seen as the result of the requirements of capital. Such a statement may seem to lend itself to an instrumentalist and/or mechanistic view of the state and of EMBRAPA as an institution in the state apparatus, i.e., that state policies necessarily correspond to the interest of the ruling class. While EMBRAPA performs certain negative and positive selection functions (see discussion in Chapter 4), it does so to maintain the viability of the social order which is determined by what Block (1977) refers to as the intersection of the intensity of class struggle and the level of economic
activity. Thus, EMBRAPA will not purely reflect the interest of capital. In other words, it is the result of contradictions which deserve further consideration.

In an attempt to identify the economic forces during the sixties that created the favorable atmosphere for change in the Brazilian research system, Pastore and Alves (1977:395-396) singled out two: (1) international and domestic demand for food and fibers which "produced a dialogue between official authorities on the one hand and the farmers, industrialists, and, especially, technicians on the other" and (2) internal crisis for food in the domestic market: "the feeding of the large urban centers suddenly became a crucial economic and political goal. Government became aware that inflation plus food shortages were the ingredients for social upheaval and radical political changes."

While Pastore and Alves tend to focus on empirically observable phenomena at the level of the market to understand the creation of EMBRAPA, their discussion does point toward what we have identified as the intersection of structural contradictions which the state apparatus needs to confront. In other words, on a structural level and within the theoretical framework of this dissertation, EMBRAPA--as state managers of the agricultural research process and as part of the state apparatus--emerged out of and must continue to confront the contradictions of maintaining a reasonable level of economic activity and controlling the mode and intensity of class struggle. The need to keep these contradictions within the limits of the interest of capital pushes the state and EMBRAPA as a state institution to perform the dual
role of accumulation—particularly by engaging in activities which would be unprofitable for private investors—and legitimation, confronting situations which may lead to "social upheaval and radical political change." EMBRAPA exercises these functions and confronts these contradictions through the negative, positive and disguising selection mechanisms.\(^2\) While the state and EMBRAPA will take on a specific class character determined by the form of accumulation occurring, at the same time it will maintain a relative autonomy as part of the division of labor between those who accumulate capital, those who labor for capital and those who manage the state apparatus.

The form of accumulation and the expansion of the capitalist mode of production in Brazil has meant a growing penetration of capitalism in agriculture characterized by an uneven distribution of commodities (more concentrated in export crops than in food crops) by farms (more present in medium and large plots than in small) and by regions of production (more in the Southeast and South regions than in others). To understand EMBRAPA solely as a function of the growing capitalist production in agriculture is to narrow the possibilities (limits) for the production of diversified levels of technology and for meeting the contradictions of the Brazilian social formation. The contradictions referred to above serve to broaden those limits, meaning that within the range of technologies produced that are structurally necessary, some are, strictly speaking, likely to be less functional than others to the ongoing expansion of capital. If this is true, then one
cannot expect the research organization, EMBRAPA, to be an easy or
direct solution to the crisis in Brazil's agriculture. If the limits
of technological development were narrow then the technological forms
compatible with those limits would be almost totally biased toward
export crops, medium and large farms and some particular regions.
Tables 6.1 through 6.4 present EMBRAPA's investments in research by
projects and regions from 1976 to 1979. In Table 6.5 these investments
are presented by states. A comparison between export and domestic
crops does not tend to show sharp differences in research investment
by EMBRAPA. If we compare, for example, investments in soybeans (an
important export crop) with that in rice and beans (two basic Brazilian
food crops) an emphasis on soybeans cannot be found. However, a
thorough comparison is not possible utilizing these tables. Due to the
specialized research institutes for some export crops such as coffee
(Brazilian Institute of Coffee, IBC), sugar cane (Institute for Sugar
and Alcohol, IAA), and cocoa (Commission for Cocoa, CEPLAC), state in-
vestment figures are not available in the Tables presented here. These
institutes do not form part of the EMBRAPA agricultural research process.
These three crops, historically the basis for accumulation in agricul-
ture, remain closely tied to certain fractions of the capitalist class.
This point, however, indicates the limits in which EMBRAPA itself must
function in attempting to respond to the overall interests of capital
and in its selection of agricultural research policies. Moreover, the
previous discussion about the articulation, functionality and
### TABLE 6.1

EMBRAPA's Investment in Agricultural Research by Project
Midwest Region, 1976-1979

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>9,317</td>
<td>11,513</td>
<td>16,772</td>
<td>21,116</td>
</tr>
<tr>
<td>Cotton</td>
<td>--</td>
<td>965</td>
<td>1,778</td>
<td>2,784</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>14,792</td>
<td>20,708</td>
<td>30,376</td>
<td>43,194</td>
</tr>
<tr>
<td>Dairy</td>
<td>--</td>
<td>--</td>
<td>1,312</td>
<td>--</td>
</tr>
<tr>
<td>Beans</td>
<td>5,283</td>
<td>8,091</td>
<td>13,649</td>
<td>23,170</td>
</tr>
<tr>
<td>Fruits</td>
<td>2,059</td>
<td>2,498</td>
<td>5,726</td>
<td>9,075</td>
</tr>
<tr>
<td>Manioc</td>
<td>306</td>
<td>446</td>
<td>1,015</td>
<td>4,618</td>
</tr>
<tr>
<td>Corn</td>
<td>636</td>
<td>735</td>
<td>598</td>
<td>2,928</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5,840</td>
<td>7,885</td>
<td>13,961</td>
<td>21,323</td>
</tr>
<tr>
<td>&quot;Cerrados&quot; Program</td>
<td>24,510</td>
<td>30,111</td>
<td>46,452</td>
<td>61,736</td>
</tr>
<tr>
<td>Genetic Resources</td>
<td>4,293</td>
<td>6,541</td>
<td>6,559</td>
<td>7,325</td>
</tr>
<tr>
<td>Soil</td>
<td>694</td>
<td>1,013</td>
<td>3,146</td>
<td>6,211</td>
</tr>
<tr>
<td>Basic Seeds</td>
<td>1,377</td>
<td>20,691</td>
<td>48,134</td>
<td>92,832</td>
</tr>
<tr>
<td>Soybeans</td>
<td>2,675</td>
<td>2,636</td>
<td>5,037</td>
<td>12,285</td>
</tr>
<tr>
<td>Wheat</td>
<td>2,864</td>
<td>1,616</td>
<td>1,953</td>
<td>3,668</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>--</td>
<td>625</td>
<td>8,896</td>
<td>71,693</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>74,646</td>
<td>116,074</td>
<td>205,364</td>
<td>383,958</td>
</tr>
</tbody>
</table>

**SOURCE:** DDM/EMBRAPA

*Current prices.*

*Budget of 1979.*
### TABLE 6.2
EMBRAPA's Investment in Agricultural Research by Project
Southeast Region, 1976-1979

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>1,166</td>
<td>3,168</td>
<td>4,973</td>
<td>11,495</td>
</tr>
<tr>
<td>Cotton</td>
<td>2,254</td>
<td>2,391</td>
<td>6,388</td>
<td>6,865</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>3,984</td>
<td>12,704</td>
<td>15,500</td>
<td>23,825</td>
</tr>
<tr>
<td>Dairy</td>
<td>28,294</td>
<td>31,222</td>
<td>51,430</td>
<td>74,851</td>
</tr>
<tr>
<td>Beans</td>
<td>1,477</td>
<td>1,924</td>
<td>4,468</td>
<td>11,585</td>
</tr>
<tr>
<td>Fruits</td>
<td>4,146</td>
<td>8,718</td>
<td>11,197</td>
<td>24,464</td>
</tr>
<tr>
<td>Manioc</td>
<td>896</td>
<td>1,972</td>
<td>2,760</td>
<td>8,918</td>
</tr>
<tr>
<td>Corn</td>
<td>10,956</td>
<td>16,447</td>
<td>27,972</td>
<td>35,619</td>
</tr>
<tr>
<td>Vegetables</td>
<td>5,050</td>
<td>8,100</td>
<td>12,866</td>
<td>22,457</td>
</tr>
<tr>
<td>Genetic Resources</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,865</td>
</tr>
<tr>
<td>Rubber Tree</td>
<td>--</td>
<td>--</td>
<td>926</td>
<td>1,800</td>
</tr>
<tr>
<td>Soil</td>
<td>10,791</td>
<td>20,382</td>
<td>52,076</td>
<td>70,631</td>
</tr>
<tr>
<td>Pork and Poultry</td>
<td>5,293</td>
<td>6,030</td>
<td>8,319</td>
<td>17,217</td>
</tr>
<tr>
<td>Basic Seeds</td>
<td>--</td>
<td>--</td>
<td>4,408</td>
<td>6,157</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1,508</td>
<td>2,364</td>
<td>2,171</td>
<td>2,847</td>
</tr>
<tr>
<td>Sorghum</td>
<td>6,360</td>
<td>12,051</td>
<td>15,701</td>
<td>16,067</td>
</tr>
<tr>
<td>Food and Agricultural Technology</td>
<td>4,107</td>
<td>7,088</td>
<td>13,536</td>
<td>16,848</td>
</tr>
<tr>
<td>Wheat</td>
<td>254</td>
<td>284</td>
<td>346</td>
<td>1,582</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>5,873</td>
<td>18,555</td>
<td>29,827</td>
<td>50,644</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>92,409</td>
<td>153,400</td>
<td>264,864</td>
<td>405,768</td>
</tr>
</tbody>
</table>

**SOURCE:** DDM/EMBRAPA

*a* Current Prices.

*b* Budget of 1979
TABLE 6.3

EMBRAPA's Investment in Agricultural Research by Project
Northeast Region, 1976-1979

<table>
<thead>
<tr>
<th>Project</th>
<th>1976</th>
<th>1977</th>
<th>1978</th>
<th>1979b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>4,321</td>
<td>8,086</td>
<td>10,028</td>
<td>14,165</td>
</tr>
<tr>
<td>Cotton</td>
<td>7,378</td>
<td>17,504</td>
<td>31,391</td>
<td>43,865</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>6,180</td>
<td>11,714</td>
<td>11,778</td>
<td>15,925</td>
</tr>
<tr>
<td>Dairy</td>
<td>3,486</td>
<td>6,100</td>
<td>3,509</td>
<td>5,859</td>
</tr>
<tr>
<td>Sheep Raising</td>
<td>2,173</td>
<td>7,691</td>
<td>10,195</td>
<td>12,722</td>
</tr>
<tr>
<td>Beans</td>
<td>7,460</td>
<td>3,647</td>
<td>7,583</td>
<td>14,806</td>
</tr>
<tr>
<td>Fruit</td>
<td>18,220</td>
<td>21,672</td>
<td>27,569</td>
<td>40,917</td>
</tr>
<tr>
<td>Manioc</td>
<td>5,532</td>
<td>12,714</td>
<td>17,169</td>
<td>30,480</td>
</tr>
<tr>
<td>Corn</td>
<td>2,297</td>
<td>4,775</td>
<td>7,444</td>
<td>14,158</td>
</tr>
<tr>
<td>Vegetables</td>
<td>305</td>
<td>1,089</td>
<td>5,191</td>
<td>10,070</td>
</tr>
<tr>
<td>Semi-aric Tropic</td>
<td>11,626</td>
<td>20,318</td>
<td>27,887</td>
<td>53,681</td>
</tr>
<tr>
<td>Rubber Tree</td>
<td>1,198</td>
<td>2,577</td>
<td>5,150</td>
<td>--</td>
</tr>
<tr>
<td>Soil</td>
<td>40</td>
<td>141</td>
<td>2,384</td>
<td>3,048</td>
</tr>
<tr>
<td>Basic Seeds</td>
<td>--</td>
<td>--</td>
<td>665</td>
<td>2,506</td>
</tr>
<tr>
<td>Soybeans</td>
<td>--</td>
<td>--</td>
<td>1,851</td>
<td>4,008</td>
</tr>
<tr>
<td>Sorghum</td>
<td>763</td>
<td>1,000</td>
<td>4,527</td>
<td>6,367</td>
</tr>
<tr>
<td>Wheat</td>
<td>230</td>
<td>307</td>
<td>724</td>
<td>581</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1,198</td>
<td>11,616</td>
<td>18,560</td>
<td>13,432</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>62,407</td>
<td>130,951</td>
<td>194,605</td>
<td>286,590</td>
</tr>
</tbody>
</table>

**SOURCE:** DDM/EMBRAPA

a Current Prices.
b Budget of 1979.
TABLE 6.4
EMBRAPA's Investment in Agricultural Research by Project
Northern Region, 1976-1979

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>353</td>
<td>1,457</td>
<td>2,423</td>
<td>2,348</td>
</tr>
<tr>
<td>Beef Cattle</td>
<td>5,461</td>
<td>12,183</td>
<td>13,752</td>
<td>10,028</td>
</tr>
<tr>
<td>Beans</td>
<td>1,681</td>
<td>3,362</td>
<td>2,227</td>
<td>3,404</td>
</tr>
<tr>
<td>Fruit</td>
<td>33</td>
<td>87</td>
<td>1,618</td>
<td>1,968</td>
</tr>
<tr>
<td>Manioc</td>
<td>904</td>
<td>1,878</td>
<td>2,190</td>
<td>2,589</td>
</tr>
<tr>
<td>Corn</td>
<td>1,908</td>
<td>3,991</td>
<td>2,461</td>
<td>2,990</td>
</tr>
<tr>
<td>Vegetables</td>
<td>--</td>
<td>--</td>
<td>3,551</td>
<td>3,516</td>
</tr>
<tr>
<td>Humid Tropic</td>
<td>14,288</td>
<td>27,504</td>
<td>41,871</td>
<td>63,940</td>
</tr>
<tr>
<td>Rubber Tree</td>
<td>11,415</td>
<td>15,450</td>
<td>20,372</td>
<td>22,874</td>
</tr>
<tr>
<td>Soil</td>
<td>--</td>
<td>--</td>
<td>657</td>
<td>1,952</td>
</tr>
<tr>
<td>Soybeans</td>
<td>--</td>
<td>--</td>
<td>683</td>
<td>771</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1,398</td>
<td>3,201</td>
<td>8,046</td>
<td>10,287</td>
</tr>
</tbody>
</table>

TOTAL            | 37,441| 69,113| 99,851| 126,667|

SOURCE: DDM/EMBRAPA

a Current Prices
b Miscellaneous
TABLE 6.5

EMBRAPA's Investment in Agricultural Research by State
Southern Region, 1976-1979

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Parana</td>
<td>28,844</td>
<td>43,429</td>
<td>62,553</td>
<td>114,865</td>
</tr>
<tr>
<td>Santa Catarina</td>
<td>21,838</td>
<td>18,018</td>
<td>24,544</td>
<td>46,680</td>
</tr>
<tr>
<td>Rio Grande do Sul</td>
<td>36,690</td>
<td>71,775</td>
<td>112,433</td>
<td>216,361</td>
</tr>
<tr>
<td>TOTAL</td>
<td>87,372</td>
<td>133,222</td>
<td>199,530</td>
<td>377,906</td>
</tr>
</tbody>
</table>

SOURCE: DDM/EMBRAPA

*Current Prices

**Budget of 1979

contradictions of the different forms of production together with the available data seem to indicate that the limits put on the creation of agricultural research technology by the forms of accumulation in Brazil are rather broad and contradictory.

For example, let's consider the problem of agricultural shortage (especially of food, but also of export crops for an expanding international market). Table 6.6 shows the evolution of food prices with respect to industrial prices in Brazil. Three sub-periods have been identified in which food prices increased more rapidly than in industry: 1950-1954 (Smith, 1969), 1960-1963 (Nicholls, 1975) and 1969-1974...
### TABLE 6.6

Evolution of the Terms of Trade Agriculture-Industry 1949-1975
(1948=100; Triennial Moving Average)

<table>
<thead>
<tr>
<th>Year</th>
<th>Internal Market</th>
<th>External Market I</th>
<th>External Market II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1949</td>
<td>94.08</td>
<td>98.54</td>
<td>127.33</td>
</tr>
<tr>
<td>1950</td>
<td>85.81</td>
<td>109.84</td>
<td>145.14</td>
</tr>
<tr>
<td>1951</td>
<td>85.88</td>
<td>111.13</td>
<td>152.36</td>
</tr>
<tr>
<td>1952</td>
<td>95.38</td>
<td>103.72</td>
<td>139.80</td>
</tr>
<tr>
<td>1953</td>
<td>105.76</td>
<td>86.05</td>
<td>140.29</td>
</tr>
<tr>
<td>1954</td>
<td>111.04</td>
<td>82.60</td>
<td>142.30</td>
</tr>
<tr>
<td>1955</td>
<td>109.86</td>
<td>82.56</td>
<td>141.11</td>
</tr>
<tr>
<td>1956</td>
<td>109.90</td>
<td>83.25</td>
<td>128.24</td>
</tr>
<tr>
<td>1957</td>
<td>108.46</td>
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<td>1958</td>
<td>103.10</td>
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<td>1959</td>
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<td>1960</td>
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<td>1961</td>
<td>114.12</td>
<td>85.74</td>
<td>79.83</td>
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<tr>
<td>1962</td>
<td>119.10</td>
<td>78.54</td>
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<td>119.70</td>
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<td>1965</td>
<td>103.94</td>
<td>81.06</td>
<td>94.54</td>
</tr>
<tr>
<td>1966</td>
<td>105.78</td>
<td>71.59</td>
<td>80.47</td>
</tr>
<tr>
<td>1967</td>
<td>107.13</td>
<td>68.59</td>
<td>74.82</td>
</tr>
<tr>
<td>1968</td>
<td>104.00</td>
<td>66.86</td>
<td>76.79</td>
</tr>
<tr>
<td>1969</td>
<td>98.34</td>
<td>67.41</td>
<td>81.16</td>
</tr>
<tr>
<td>1970</td>
<td>100.76</td>
<td>71.58</td>
<td>86.38</td>
</tr>
<tr>
<td>1971</td>
<td>103.12</td>
<td>76.72</td>
<td>93.51</td>
</tr>
<tr>
<td>1972</td>
<td>118.94</td>
<td>90.35</td>
<td>105.43</td>
</tr>
<tr>
<td>1973</td>
<td>130.60</td>
<td>97.95</td>
<td>114.88</td>
</tr>
<tr>
<td>1974</td>
<td>138.82</td>
<td>101.32</td>
<td>125.70</td>
</tr>
<tr>
<td>1975</td>
<td>137.86</td>
<td>102.19</td>
<td>147.18</td>
</tr>
</tbody>
</table>

**SOURCE:** Mello (1978:203)

1/ Triennial moving average of the relation between prices received by São Paulo's farmers and industrial price index (Index 18 of Conjuntura Econômica), which includes the following industries: chemical, metals, metallurgic products, leather and furs, fabric, clothing and shoes.

2/ Products: potatoes, manioc, rice, beans, tomatoes, onions, eggs, pork and milk.

3/ Products: cotton, soybeans, peanuts, castor beans and tea.

4/ Products: the above five, plus coffee, sugar, oranges and bananas.
(Mello, 1978). This last period coincides with the creation and effective operation of EMBRAPA.

The shortage of food in urban areas which—in increasing the chances of struggles for wage—contribute to both profit squeeze and "upheaval and radical political changes" as Pastore and Alves (1977:396) have correctly pointed out. The alternative solution to the contradiction between agricultural production and industrial production mentioned above (and to be returned to below) generates new forms of contradictions which must be addressed by EMBRAPA. Those forms will trace new forms of contradictions which will set the limits to technological production.

While it is not a satisfactory methodological procedure to try to explain the emergence of EMBRAPA through a correlation which changing market prices (i.e., to changes in the sphere of circulation alone), the use of such data does partially point toward the nature of the contradictions which EMBRAPA must confront. EMBRAPA's emergence coincides with a particular period of capitalist expansion and is a partial solution to some specific contradictions of this process in Brazil. Overall, accumulation in Brazil has been linked with the existence of non-capitalist and relatively less advanced forms of capitalist relations in agriculture. This is to say that the overall capitalist accumulation in Brazil has been dependent on the reproduction of non-capitalist and less advanced capitalist relations existing in agriculture. But it is wrong to conclude from this that it is the existence of non-capitalist and less advanced capitalist
relations which are responsible for the growth of the Brazilian economy. This would be the content of a pure and simple statement of the "functionality of agriculture" thesis critiqued earlier. The economic and social development[^3] which Brazil has reached is certainly not due to the low productivity in agriculture, but rather to the growing productivity obtained by industrial production (Silva, 1976:31).

[^3]:  

One of the functionalities (which is at the same time a contradiction) of the less advanced forms of agricultural production resides in securing the expansion of agricultural production, especially the supply of cheap food to the urban centers. The constant capitalist penetration in agriculture (which results from overall capitalist expansion in Brazil) together with the limits reached by extensive agriculture practice (see Dias, 1978:ch. 4) have upset the "traditional" equilibrium of the different forms of accumulation. The transformation of the Brazilian research system is a product of these contradictions.

EMBRAPA can be seen as an important state action that tends to undermine impediments to accumulation brought about by the contradictions generated in production. Those impediments to accumulation in Brazil refer to the growing non-reproductive character of accumulation. As was discussed in Chapter 4, changes in the articulation of the forces and relations of production mean not only changes on the limits of variability and articulation of the forms of accumulation, but also
changes in the ways in which the forms of accumulation reproduce the forces and relations of production (limits of functional compatibility).

The problem of agricultural shortages was to be addressed by EMBRAPA via increases in agricultural production. Consequently, reformulations of the research, extension and credit systems received top priority. The emphasis was to dynamize the forces of production in correspondence to the goals of specific class practices.

The contradiction among different conditions of existence for accumulation in Brazilian agriculture (for example, signalled by food price increases) and between these conditions and those predominantly say, in industry, explain the emergence of EMBRAPA and its policy reformulation. The contradiction we speak of may be summarized in the following terms: the penetration of capitalist relations into agriculture generates its own impediments to accumulation by steadily undermining an agricultural subsistence sector which has in the past crucially functioned to provide cheap food to urban workers and hence, to promote capitalist accumulation in the urban sector. Shaped by this overall and contradictory process of capitalist accumulation, contradictions in EMBRAPA unfold as well. One way to examine these contradictions is to explore the problem of the limits that accumulation (with its contradictions) places on the creation of agricultural research technology.
EMBRAPA's Policies to Confront the Contradictions of Accumulation

The forms of technology compatible with those limits constitute, thus, a vast array. One example of this is EMBRAPA's program of elaboration of technological packages. As Table 6.7 shows, from 1974 to 1979, the 346 meetings of elaboration of technological packages— involving 2,550 researchers, 3,744 extensionists and 3,906 farmers—were not concentrated in the South and Southeast regions alone. A large number and percentage of these meetings were located, for example, in the Northeast (36%). However, when we pass from the program of technological package developed by EMBRAPA to an aggregated analysis of publications in agricultural research in Brazil during the period 1927-1977, the uneven distribution of research by region is evident. As Table 6.8 reveals, the concentration of agricultural research is located, by far, in the Southeast region (78.9% of the total), and within the Southeast region, in the state of São Paulo (see Table 6.9). Agricultural research in São Paulo alone, represents 62.5% of the total computed to Brazil. It is only in the period 1970-1977 which corresponds to the reformulation of the Brazilian agricultural research system and consequent creation of EMBRAPA, that the agricultural research in Brazil (São Paulo excluded) acquires real importance (61.8% of the total). During this period (1970-1977) São Paulo developed 1,078 publications and the rest of Brazil 1,741. This relative increase of research in other Brazilian regions relative to São Paulo is mainly a consequence of the intensification of research on some export crops
<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Meetings</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>64</td>
<td>18.6</td>
</tr>
<tr>
<td>Southeast</td>
<td>65</td>
<td>19.0</td>
</tr>
<tr>
<td>Northeast</td>
<td>124</td>
<td>36.0</td>
</tr>
<tr>
<td>North</td>
<td>52</td>
<td>15.1</td>
</tr>
<tr>
<td>Middle-west</td>
<td>39</td>
<td>11.3</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>344</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

*Source: DDT/EMBRAPA*
Table 6.8

Number of Publications in Agricultural Research and Agricultural Research Technology in Brazil According to Regions, 1927-1977

<table>
<thead>
<tr>
<th></th>
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<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>--</td>
<td>--</td>
<td>17</td>
<td>108</td>
<td>91</td>
<td>518</td>
<td>734</td>
</tr>
<tr>
<td>Southeast</td>
<td>157</td>
<td>513</td>
<td>999</td>
<td>926</td>
<td>1578</td>
<td>1752</td>
<td>5925</td>
</tr>
<tr>
<td>Northeast</td>
<td>--</td>
<td>6</td>
<td>12</td>
<td>67</td>
<td>111</td>
<td>413</td>
<td>609</td>
</tr>
<tr>
<td>North</td>
<td>--</td>
<td>--</td>
<td>19</td>
<td>57</td>
<td>28</td>
<td>102</td>
<td>206</td>
</tr>
<tr>
<td>Midwest</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>34</td>
<td>34</td>
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<tr>
<td>TOTAL</td>
<td>157</td>
<td>519</td>
<td>1047</td>
<td>1158</td>
<td>1808</td>
<td>2819</td>
<td>7508</td>
</tr>
</tbody>
</table>

SOURCE: Silva, Fonseca and Martin (1979:11)
TABLE 6.9

Number of Publications in Agricultural Research and Agricultural Research Technology in Sao Paulo, 1927-1977

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1927-29</td>
<td>157</td>
<td>503</td>
<td>692</td>
<td>822</td>
<td>1,438</td>
<td>1,078</td>
<td>4,690</td>
</tr>
</tbody>
</table>

SOURCE: Silva, Fonseca and Martin (1979:11)

cocoa, developed by CEPLAC; coffee, developed by IBC; and soybeans, developed by EMBRAPA) and on one food crop (wheat, developed by EMBRAPA) (see Silva, Fonseca and Martin, 1979:10).

EMBRAPA's program of elaboration of technological packages began in 1974. At that time (while the selection of personnel was being made, the new model of research being implanted, and an aggressive program of capacitation of human resources being initiated) the intention was "to put out of the drawers and bookcases" the technological knowledge already created and/or adapted by the old system (DNPEA). The objective was to elaborate distinct technological packages to be immediately incorporated into the differentiated Brazilian production system. Several documents in EMBRAPA stressed the goals of each technological package: to achieve technical and economic efficiency. Within this context, the variable under analysis was not only the technology per se, but also the elements of the social formation such as the form of production, the type of farms, commodities and regions and the characteristics of the markets of inputs and commodities. With the diversification of
variables under scientific investigation, the need for a multidisciplinary team of researchers became a recognized necessity. In fact, socio-economic investigation has been increasingly included in agronomic investigation. The technological package program which reached its maximum point in 1976 (280 technological packages elaborated representing 34.1% of the total—see Table 6.10) has been continued through a program of technical training of extensionists which reached its maximum point in 1979 (with 46.3% of the total of training—see Table 6.11).

The variety of commodities benefiting from the program (see Table 6.10) is a sign that not only export crops but also those domestic crops (such as beans, rice, manioc and corn) produced by small and subsistence farmers (who demanded low level of technological practices) were within the limits of EMBRAPA's possibilities. But these possibilities (or amplitude of limits) did not occur at random. A set of political, economic and social obstacles to capitalist accumulation began to make clearer the necessity for the state's technical-scientific apparati to adapt and to reorganize itself in order to face a growing demand for technology originating in the capitalist sector of agricultural production. This set of obstacles to accumulation can be shown in the contradiction represented by the expansion of capitalism in agriculture and the consequent problems of food supply to the urban centers. The surplus produced by the non-capitalist sector (for example, by subsistence units) continued (and still continues) to be crucial to the supply of cheap food to the urban centers. It is this contradiction represented by the expansion of capitalism in agriculture and the
Table 6.10

Number and Percentage of Technological Packages Developed by EMBRAPA, Number and Percentage of Meetings, Number of Commodities Attended, and Participation of Researchers, Extensionists and Farmers, by Year, 1974-1979

<table>
<thead>
<tr>
<th>Year</th>
<th>Technological Package Number</th>
<th>Meetings No.</th>
<th>%</th>
<th>Number of Commodities</th>
<th>Participation Researchers</th>
<th>Extensionists</th>
<th>Farmers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1974</td>
<td>69</td>
<td>21</td>
<td>6.1</td>
<td>10</td>
<td>369</td>
<td>226</td>
<td>272</td>
</tr>
<tr>
<td>1975</td>
<td>221</td>
<td>73</td>
<td>21.2</td>
<td>27</td>
<td>992</td>
<td>619</td>
<td>847</td>
</tr>
<tr>
<td>1976</td>
<td>280</td>
<td>130</td>
<td>37.8</td>
<td>29</td>
<td>1,324</td>
<td>931</td>
<td>1,603</td>
</tr>
<tr>
<td>1977</td>
<td>137</td>
<td>65</td>
<td>18.9</td>
<td>21</td>
<td>687</td>
<td>441</td>
<td>693</td>
</tr>
<tr>
<td>1978</td>
<td>60</td>
<td>27</td>
<td>7.9</td>
<td>16</td>
<td>163</td>
<td>121</td>
<td>278</td>
</tr>
<tr>
<td>1979</td>
<td>53</td>
<td>28</td>
<td>8.1</td>
<td>14</td>
<td>209</td>
<td>212</td>
<td>213</td>
</tr>
<tr>
<td>Total</td>
<td>820</td>
<td>344</td>
<td>100.0</td>
<td>117</td>
<td>3,744</td>
<td>2,550</td>
<td>3,906</td>
</tr>
</tbody>
</table>

SOURCE: DDT/EMBRAPA
Table 6.11
Number of Technical Trainings for Extensionists Developed by EMBRAPA, 1975-1979

<table>
<thead>
<tr>
<th>Year</th>
<th>Trainings Number</th>
<th>%</th>
<th>Number of Trained Extensionists</th>
<th>Number of Commodities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>31</td>
<td>8.1</td>
<td>1,087</td>
<td>11</td>
</tr>
<tr>
<td>1976</td>
<td>66</td>
<td>17.3</td>
<td>1,761</td>
<td>10</td>
</tr>
<tr>
<td>1977</td>
<td>43</td>
<td>11.3</td>
<td>1,267</td>
<td>4</td>
</tr>
<tr>
<td>1978</td>
<td>65</td>
<td>17.0</td>
<td>1,430</td>
<td>13</td>
</tr>
<tr>
<td>1979</td>
<td>177</td>
<td>46.3</td>
<td>1,679</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>382</td>
<td>100.0</td>
<td>7,224</td>
<td>47</td>
</tr>
</tbody>
</table>

SOURCE: DDT/EMBRAPA

continued importance of non-capitalist agriculture which make the forms of low technology (for example, the non-sophisticated forms of technological packages) to small and subsistence farmers compatible with the new limits set by the overall Brazilian accumulation process on the process of creation of agricultural research technology.

When the number of research publications in six important export crops (coffee, soybeans, sugar cane, cotton, citrus and cocoa) and in six important food crops (beans, rice, wheat, potato, manioc and corn) are compared over years (1927-1977), the percentage in favor of export crops covers the entire period (see Table 6.12). During the 50 years
Table 6.12

Number of Publications in Agricultural Research and Agricultural Research Technology for Six Selected Export Crops and Six Selected Food Crops in Brazil, 1927-1977

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>23</td>
<td>38</td>
<td>71</td>
<td>132</td>
<td>163</td>
<td>457</td>
<td>884</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>12</td>
<td>25</td>
<td>189</td>
<td>236</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>11</td>
<td>70</td>
<td>45</td>
<td>74</td>
<td>96</td>
<td>114</td>
<td>410</td>
</tr>
<tr>
<td>Cotton</td>
<td>12</td>
<td>50</td>
<td>38</td>
<td>48</td>
<td>115</td>
<td>63</td>
<td>326</td>
</tr>
<tr>
<td>Citrus</td>
<td>2</td>
<td>35</td>
<td>64</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>261</td>
</tr>
<tr>
<td>Cocoa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>9</td>
<td>81</td>
<td>93</td>
</tr>
<tr>
<td>Subtotal</td>
<td>49</td>
<td>198</td>
<td>222</td>
<td>309</td>
<td>468</td>
<td>964</td>
<td>2,210</td>
</tr>
<tr>
<td>%</td>
<td>(75.4)</td>
<td>(80.2)</td>
<td>(57.8)</td>
<td>(60.7)</td>
<td>(55.5)</td>
<td>(59.4)</td>
<td>(60.2)</td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>6</td>
<td>92</td>
<td>143</td>
<td>259</td>
</tr>
<tr>
<td>Rice</td>
<td>1</td>
<td>4</td>
<td>18</td>
<td>59</td>
<td>89</td>
<td>132</td>
<td>303</td>
</tr>
<tr>
<td>Wheat</td>
<td>7</td>
<td>1</td>
<td>14</td>
<td>15</td>
<td>17</td>
<td>207</td>
<td>261</td>
</tr>
<tr>
<td>Potato</td>
<td>5</td>
<td>15</td>
<td>51</td>
<td>51</td>
<td>80</td>
<td>30</td>
<td>232</td>
</tr>
<tr>
<td>Manioc</td>
<td>2</td>
<td>5</td>
<td>28</td>
<td>16</td>
<td>15</td>
<td>20</td>
<td>86</td>
</tr>
<tr>
<td>Corn</td>
<td>1</td>
<td>24</td>
<td>33</td>
<td>53</td>
<td>83</td>
<td>127</td>
<td>321</td>
</tr>
<tr>
<td>Subtotal</td>
<td>16</td>
<td>49</td>
<td>162</td>
<td>200</td>
<td>376</td>
<td>659</td>
<td>1,462</td>
</tr>
<tr>
<td>%</td>
<td>(24.6)</td>
<td>(19.8)</td>
<td>(42.2)</td>
<td>(39.3)</td>
<td>(44.5)</td>
<td>(40.6)</td>
<td>(39.8)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>65</td>
<td>247</td>
<td>384</td>
<td>509</td>
<td>844</td>
<td>1,623</td>
<td>3,672</td>
</tr>
</tbody>
</table>

SOURCE: Silva, Fonseca and Martin (1979:31)
considered in Table 6.12, the six selected export crops received 60.2% of the research activity. From 1930 to 1939 the percentage was 80.2 and from 1970 to 1977, 59.4%. However, a more complete but non-proportional (in terms of number of commodities) comparison between export and food crop research (see Table 6.13) shows that the dominance of export crop research decreases sharply. In Table 6.13, the export crop research visibly dominates the food crop research during the sub-periods of 1927-1929 (31.8% against 12.8% for food crop research, being 7.6% for other crops and 47.8% for research not related to crops) 1930-1939 (39.3% against 18.9% for food crop), 1950-1959 (28.9% against 27.1% for food crops), and 1970-1977 (36.0% against 34.8% for food crops). Considering the whole period (1927-1977), research on export crops dominates that on food crops (31.3% against 30.6% for food crops). The two decades that the percentage of research on food crops was higher than that on export crops were 1940-1949 (with 27.2% of research on food crop and 22.5% on export crops) and 1960-1969 (with 33.3% of research on food crops and 28.4% on export crops).

Incorporating the specific contradictions of the Brazilian social formation, EMBRAPA is preparing to face the needs of further expansion of capitalism in agriculture. To EMBRAPA, one of the great challenges is to make an effective contribution to the transformation of commercial agriculture in Brazil, i.e., "to deepen this process of modernization and to diffuse it in regions not yet reached by it, mainly in Northeast" (EMBRAPA, 1973:7). The already-mentioned technological package program was one of the first strategies. This program sought to
Table 6.13

Number of Publications in Agricultural Research and Agricultural Research Technology in Brazil, According to Crop Commodities, 1927-1977

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coffee</td>
<td>23</td>
<td>38</td>
<td>71</td>
<td>132</td>
<td>163</td>
<td>457</td>
<td>884</td>
</tr>
<tr>
<td>Cotton</td>
<td>12</td>
<td>50</td>
<td>38</td>
<td>48</td>
<td>115</td>
<td>63</td>
<td>326</td>
</tr>
<tr>
<td>Citrus</td>
<td>2</td>
<td>35</td>
<td>64</td>
<td>40</td>
<td>60</td>
<td>60</td>
<td>261</td>
</tr>
<tr>
<td>Sugar Cane</td>
<td>11</td>
<td>70</td>
<td>45</td>
<td>74</td>
<td>96</td>
<td>114</td>
<td>410</td>
</tr>
<tr>
<td>Peanuts</td>
<td>-</td>
<td>2</td>
<td>5</td>
<td>16</td>
<td>37</td>
<td>42</td>
<td>102</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1</td>
<td>5</td>
<td>4</td>
<td>12</td>
<td>25</td>
<td>189</td>
<td>236</td>
</tr>
<tr>
<td>Mamona</td>
<td>1</td>
<td>4</td>
<td>9</td>
<td>10</td>
<td>8</td>
<td>9</td>
<td>41</td>
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<tr>
<td>Cocoa</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>9</td>
<td>81</td>
<td>93</td>
</tr>
<tr>
<td>Subtotal</td>
<td>50</td>
<td>204</td>
<td>236</td>
<td>335</td>
<td>513</td>
<td>1,015</td>
<td>2,353</td>
</tr>
<tr>
<td>Food</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potato</td>
<td>5</td>
<td>15</td>
<td>51</td>
<td>51</td>
<td>80</td>
<td>30</td>
<td>232</td>
</tr>
<tr>
<td>Corn</td>
<td>1</td>
<td>24</td>
<td>33</td>
<td>53</td>
<td>83</td>
<td>127</td>
<td>321</td>
</tr>
<tr>
<td>Beans</td>
<td>-</td>
<td>-</td>
<td>18</td>
<td>6</td>
<td>92</td>
<td>143</td>
<td>259</td>
</tr>
<tr>
<td>Tomato</td>
<td>2</td>
<td>3</td>
<td>27</td>
<td>25</td>
<td>40</td>
<td>57</td>
<td>154</td>
</tr>
<tr>
<td>Rice</td>
<td>1</td>
<td>4</td>
<td>18</td>
<td>59</td>
<td>89</td>
<td>132</td>
<td>303</td>
</tr>
<tr>
<td>Manioc</td>
<td>2</td>
<td>5</td>
<td>28</td>
<td>16</td>
<td>15</td>
<td>20</td>
<td>86</td>
</tr>
<tr>
<td>Wheat</td>
<td>7</td>
<td>1</td>
<td>14</td>
<td>15</td>
<td>17</td>
<td>207</td>
<td>261</td>
</tr>
<tr>
<td>Banana</td>
<td>-</td>
<td>9</td>
<td>7</td>
<td>6</td>
<td>12</td>
<td>26</td>
<td>60</td>
</tr>
<tr>
<td>Onion</td>
<td>1</td>
<td>-</td>
<td>11</td>
<td>10</td>
<td>13</td>
<td>25</td>
<td>60</td>
</tr>
<tr>
<td>Vegetables</td>
<td>-</td>
<td>2</td>
<td>33</td>
<td>22</td>
<td>70</td>
<td>92</td>
<td>219</td>
</tr>
<tr>
<td>Fruits</td>
<td>1</td>
<td>35</td>
<td>45</td>
<td>51</td>
<td>91</td>
<td>123</td>
<td>346</td>
</tr>
<tr>
<td>Subtotal</td>
<td>20</td>
<td>98</td>
<td>285</td>
<td>314</td>
<td>602</td>
<td>982</td>
<td>2,301</td>
</tr>
<tr>
<td>Other crops</td>
<td>12</td>
<td>28</td>
<td>96</td>
<td>78</td>
<td>139</td>
<td>190</td>
<td>543</td>
</tr>
<tr>
<td>Research not related to crops</td>
<td>75</td>
<td>189</td>
<td>430</td>
<td>431</td>
<td>554</td>
<td>632</td>
<td>2,311</td>
</tr>
<tr>
<td>TOTAL</td>
<td>157</td>
<td>519</td>
<td>1,047</td>
<td>1,158</td>
<td>1,808</td>
<td>2,819</td>
<td>7,508</td>
</tr>
</tbody>
</table>

SOURCE: Silva, Fonseca and Martin (1979:31)
make an aggressive use of the technological knowledge already created and, with the input of extensionists' and farmers' experience, to put it into differentiated systems of technology. At the same time that this program was being developed, another important one was underway: the graduate program.

To make an effective contribution to commercial agriculture meant that EMBRAPA would create agricultural technology under a higher level of scientific expertise. Hayami and Ruttan (1971:57), for example, defend the thesis that commercial farmers are induced to make technological changes by shifts in relative prices. These farmers press the public research organizations to develop the new technology (i.e., a technology compatible with the shift in relative prices). Thus, the thesis is constructed under the assumption that these public research organizations are formed by "perceptive scientists and science administrators" capable of translating farmers' pressure into viable technology. The authors suggest that "improvements in human capital in the form of educated, innovative farmers, competent scientists and technicians, and perceptive public administrators and business entrepreneurs are essential if this process is to generate continuous growth in agricultural productivity" (Hayami and Ruttan, 1971:85).

In 1972, one of the characteristics of the federal research system in Brazil was that only 10 percent out of 1,902 individuals accepted as formal researchers were recognized professionals, with some kind of graduate training in research (Pastore and Alves, 1977:399). To face this situation, EMBRAPA began in 1974 a large graduate program. As
Table 6.14 shows, a total of 1,684 professionals of the Brazilian agricultural research system were sent to take courses in pursuit of M.S. or Ph.D. degrees. From this total, 513 were sent abroad (mainly to U.S. universities). Table 6.15 shows that by 1978 from the 1,340 researchers in EMBRAPA at that time, 41% had B.S. degrees, 52.4% M.S. and 6.6% Ph.D.'s. In 1979, only 37.8% of the researchers had B.S. degrees. The percentage of M.S.'s increased to 53.6% and Ph.D.'s to 8.6%. This higher level of scientific and technological competence makes the researcher's working objectives (i.e., technical efficiency, desired product characteristics, and production risk—see Pinstrup-Anderson and Franklin, 1977:418-419) more tenable. Besides these two basic programs—technological package and formation of human resources through graduate training—EMBRAPA also signified a reformulation in the model of agricultural research. A "concentrated model" of agricultural research replaced a traditional "diffuse model." The "diffuse model" has been used more successfully in developed countries such as the United States.

The basic characteristic of the "diffuse model" is the broad diversification of agricultural commodities and topics of research being investigated. The researcher is practically free in his/her choice of what to research. Within this model, the research unit follows the organizational pattern pointed out by Hayami and Ruttan (1971:53-63, 82-85). The optimum functioning of each research unit presupposes the availability of abundant financial and human resources. Human resources consist not only of a large number of researchers with graduate training
### TABLE 6.14

EMBRAPA's Graduate Program. Number of Technicians in the Program by Level, 1974-1979

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>From EMBRAPA</td>
<td>M.S.</td>
<td>267</td>
<td>152</td>
<td>232</td>
<td>54</td>
<td>76</td>
<td>54</td>
<td>835</td>
</tr>
<tr>
<td>Brazil</td>
<td>Ph.D.</td>
<td>20</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>16</td>
<td>52</td>
</tr>
<tr>
<td>Abroad</td>
<td>M.S.</td>
<td>28</td>
<td>71</td>
<td>49</td>
<td>19</td>
<td>20</td>
<td>19</td>
<td>206</td>
</tr>
<tr>
<td>Abroad</td>
<td>Ph.D.</td>
<td>19</td>
<td>28</td>
<td>21</td>
<td>15</td>
<td>33</td>
<td>30</td>
<td>146</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>334</td>
<td>258</td>
<td>305</td>
<td>92</td>
<td>131</td>
<td>119</td>
<td>1,239</td>
</tr>
<tr>
<td>From other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
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<td></td>
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<td></td>
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<tr>
<td>(financed by</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMBRAPA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>M.S.</td>
<td>32</td>
<td>23</td>
<td>56</td>
<td>35</td>
<td>78</td>
<td>53</td>
<td>277</td>
</tr>
<tr>
<td>Brazil</td>
<td>Ph.D.</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Abroad</td>
<td>M.S.</td>
<td>5</td>
<td>9</td>
<td>13</td>
<td>19</td>
<td>13</td>
<td>27</td>
<td>86</td>
</tr>
<tr>
<td>Abroad</td>
<td>Ph.D.</td>
<td>8</td>
<td>8</td>
<td>14</td>
<td>28</td>
<td>9</td>
<td>8</td>
<td>75</td>
</tr>
<tr>
<td>Subtotal</td>
<td></td>
<td>48</td>
<td>41</td>
<td>83</td>
<td>82</td>
<td>102</td>
<td>89</td>
<td>445</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td>382</td>
<td>299</td>
<td>388</td>
<td>174</td>
<td>233</td>
<td>208</td>
<td>1,684</td>
</tr>
</tbody>
</table>

**SOURCE:** DRH/EMBRAPA
### Table 6.15
Total Number of Technicians in EMBRAPA by Degree Attained, 1973–1979

<table>
<thead>
<tr>
<th>Year</th>
<th>B.S.</th>
<th>M.S.</th>
<th>Ph.D.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>12</td>
</tr>
<tr>
<td>1974</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>872</td>
</tr>
<tr>
<td>1975</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>1,037</td>
</tr>
<tr>
<td>1976</td>
<td>876</td>
<td>304</td>
<td>37</td>
<td>1,217</td>
</tr>
<tr>
<td>1977</td>
<td>701</td>
<td>464</td>
<td>53</td>
<td>1,218</td>
</tr>
<tr>
<td>1978</td>
<td>549</td>
<td>702</td>
<td>89</td>
<td>1,340</td>
</tr>
<tr>
<td>1979</td>
<td>548</td>
<td>777</td>
<td>124</td>
<td>1,449</td>
</tr>
</tbody>
</table>

**SOURCE:** DRH/EMBRAPA (Cadastro)

In research but, as well, of a large number of farmers sufficiently organized to interact with (to put pressure on) the research centers. Another important characteristic of the "diffuse model" is that it relies on the existence of a highly decentralized agricultural research system (Hayami and Ruttan, 1971:57).

Differently, the "concentrated model" of agricultural research implies the concentration of financial and human resources on a limited number of agricultural commodities. As a model of research suited to face the scarcity of financial and human resources, it limits (1) the number of the systems of production prototypes to be developed, (2) the number of commodities to be researched and (3) parts of the system of
production that deserve more attention. In the same way that the United States is a satisfactory empirical example for the "diffuse model," Brazil (EMBRAPA) is a satisfactory empirical reference for the "concentrated model." Through its commodity-oriented national research centers, EMBRAPA is structured to generate the basic technology to those commodities judged as "national priorities."

The concentration of financial and human resources in commodity-oriented national research centers—such as the national research centers for beans and rice in the state of Goiás, for wheat in the state of Rio Grande do Sul, for soybeans in the state of Paraná and for cotton in the state of Paraíba—can be seen as part of the "solution" to the accumulation crisis in Brazil. Each commodity-oriented national research center is supposed to function with highly trained technicians working on multidisciplinary teams toward the production of a different final product of research. The final product of research, identified in Chapter 1 as the system of production (S), would involve a large range of information, where the agronomic knowledge is linked with socio-economic knowledge. The rapid increase of agricultural production and productivity would signify a higher supply of cheap food to urban areas together with an increase in both the domestic supply of fibers to industry and in export crops to the external market. In Brazil, moreover, since food crops are not characteristically produced by commercial agriculture and the establishment of priorities "means that some groups of farmers may not receive the benefits of research" (Pastore and Alves, 1977:401), the "solution" to the capitalist
accumulation in Brazil (in which the creation of EMBRAPA is a constituent part) worked out since the late sixties tends to put the next crisis at a more complex level, demanding more difficult "solutions." A "solution" which is entirely functional (i.e., that does not produce new contradictions) for Brazilian capitalism is basically an impossibility. Works such as Abranche's (1978) and Munck's (1976) seem to indicate that class struggles around the state and around production in Brazil tend to become more intense. For example, the growing contradiction within the state between legitimation and accumulation is part of this process.

As the discussions in Chapters 1 and 4 indicate, the study of the relation between accumulation and the creation of agricultural research technology cannot miss the dimension that it is the articulation between the forces and relations of production which structurally limit the forms of accumulation. In our critique of the "functionality of the agriculture thesis" (based mainly on Silva, 1976, 1977, 1978), there is the indication that a form of accumulation does not necessarily reproduce a given articulation of forces and relations of production. In fact, a form of accumulation (see Chapter 4) can lie outside of the limits of functional compatibility set by the articulation of forces and relations of production, i.e., to be nonreproductive of (to contradict) that articulation. It is thus entirely possible for the limits set by the forms of accumulation on the creation of agricultural research technology to be in contradiction with a particular historical
articulation of the forces and relations of production. The actual occurrence of this possibility is one of the basic sources of crisis.

The three events in EMBRAPA highlighted in this chapter—the technological package program, the graduate training program and the reformulation of the model for agricultural research—do not lend conclusive support to Hypothesis 4.1. Rather, these events have been discussed as an indication that the contradictory forms of accumulation in Brazil have situated limits, imposed constraints and set possibilities for the creation of agricultural research technology. Besides additional techniques, the empirical verification of Hypothesis 4.1 would demand additional data and a more ample period of years under investigation.
FOOTNOTES FOR CHAPTER 6

1/ See Chapter 4, for our discussion of theory construction and the nature of "scientific progress."

2/ For a detailed discussion of our position see Chapter 4 and the work of Offe (1974), O'Connor (1973) and Block (1977).

3/ Linda Wright-Romero's forthcoming dissertation (Department of Agricultural Economics and Rural Sociology at The Ohio State University) brings an interesting critical analysis of the concept of development. There, Linda defends a conceptualization of development constructed from the point of view of labor and not of capital. Development as used by this author in this context has a content associated with growth.

4/ It needs to be observed that the work of the "Instituto Agronômico de Campinas" (IAC) (which creates and adapts technology to the state of São Paulo) is not computed in Table 6.7. The interaction between IAC and EMBRAPA has been increasing over years. Also, a large amount of research on coffee and sugar-cane are decided quite independently from EMBRAPA by the "Instituto Brasileiro do Café" (IBC) and by the "Instituto do Açucar e do Alcool" (IAA), respectively.

5/ EMBRAPA has ten commodity-oriented national research centers and three centers of natural resources. These centers work closely linked with (1) state systems and (2) the support services, such as genetic resources, soil conservation and basic seed production.
CHAPTER 7

SUMMARY AND CONCLUSIONS

The principal aim of this dissertation has been an investigation into the relationship between agricultural research technology and the accumulation of capital. The relationship that we explore is a more technical and specific expression of the commonly stated relationship between technology and society. Chapters 1 through 5 are consequently involved in the process of reformulating the problem and postulating the connections between technology and society in view of that reformulation. Chapter 6 serves as an empirical illustration of some of the connections that were postulated.

The investigation into the relationship between technology and society involved the pursuit of three broad objectives that can be summarized as: (1) a reformulation of the problem; (2) the pulling together of a theoretical framework capable of broadly explaining some of the fundamental determinants in the relation; and (3) using Brazil's research organization, EMBRAPA, as an illustration, an empirical analysis of the foregoing theoretical discussions and their reformulations. From our efforts to push ahead these objectives several conclusions can be drawn.
The purpose behind reformulating the problem of the relationship between society and technology was to deepen our explanatory capabilities. By explaining a phenomena we are interested in accounting for that phenomena. The first and most obvious issue to be confronted—and probably the most far-reaching one as well—was what is to be explained in the relationship between society and technology?

Perspectives in the Marxist debate over the primacy of the forces of production or of the relations of production were presented in order to clarify this difficult question. The crucial point on which we rejected the primacy of the forces of production thesis was an inherent incapacity to provide an explanation of the mechanisms by which a transformation (in both quantitative and qualitative senses) in the forces was possible. Forces of production (such as technologies) were seen to progress autonomously. This is an untenable solution to the problem because it cuts off the possibility of obtaining knowledge of the social reality on which the technologies were developed. Taking a position in the debate on the side of the primacy of the relations of production enabled us to reassert the importance of a search for the social determinants of technical change.

Chapter 2 covered three broad approaches: Psychological, economic and social. These consist of a great variety of works that have contributed to the investigation of the relationship between society and technology. Although many of these works provide significant contributions to our understanding of the determinants of technology, the argument was introduced that only if we conceptualize society as a social
formation, or rather, as a complex social totality consisting primarily of three distinct yet unified structures--economic, political and ideological--within which social practices are embedded, can we address the issue of the possibilities and limits to a certain level and/or form of technology.

The view taken in this dissertation admits technological advances occurring from individual genius, or that the market promoted technological advance. These relationships cannot, however, explain why creativity happens to put its energies behind a particular form of technology or why some discoveries go unnoticed. Nor can the market explain the development of technologies that are not optimally efficient by economic standards. In confronting this incapacity to explain the social structural limits and possibilities of technologies, within which these other relationships are determined, it was necessary to construct a concept of social reality within a theoretical framework that would explain technology in the sense described.

Chapters 4 and 5 provided the theoretical arguments in accordance with a conception of society as a social formation together with the location of technology within this social reality. We used Marx's theory of accumulation as a way of presenting the relations within a society and disclosing the underlying dynamics of change. Basically, two points can be made with respect to this process that have a bearing on our later empirical analysis.

First, the accumulation process is an on-going and constantly expanding system of social relations. On-going production implies
reproduction of the conditions of production and within the logic of accumulation, value must expand and hence, those conditions for reproduction of the conditions of production need to be secured at ever changing levels. Given that capital is a social relation in its real constitution, then the accumulation of capital is unmistakably involved with people and the determinations of relations among groups such as buyers and sellers, workers and owners, class fractions, and so on. Political practice is thus intrinsic to the accumulation process in the sense that it is necessarily bound up with that process throughout. Such political activity is the domain of the state. Indeed, the nature of the ties between accumulation which is often conceived of as an "economic process" and the state, typically understood as embodying "political" processes, cannot be overstated. Offe (1974) stresses that the state is not only implicated in the accumulation process but is constituted by it as well.

Second, the accumulation process is contradictory and complex. The most fundamental contradiction (fundamental in the sense that whether manifest or not it gives shape to other contradictions) is that between capital and labor within the system of production. The fundamental antagonism between capital and labor defines capitalist social relations and hence cannot be decisively overcome unless the relations themselves are transformed in fundamental ways. This basic contradiction gives rise to crises. Considerable Marxist literature has aimed to isolate and argue about the nature of the crisis. In our presentation (Chapter 4) we have stressed the complexity of the
accumulation process by showing not only that different crises can occur as Mandel's "Long Waves" theory and as Wright's (1978) stages of capitalism positions point out, but also that several different crises can be obstructing the accumulation process at the same time. This is perhaps especially the case for a rapidly developing country such as Brazil, although still unambiguously in a subordinate position in the world capitalist system.

The extensive discussion on accumulation together with the nature of various crises and the role of the state represented an attempt to specify at a theoretical level, i.e., in a determinate manner, the relations within a social formation. "Theoretical level" refers to neither a generalized description of society nor to an idealized account of what a capitalist society should be like. In Chapter 3 we show how this theoretical discussion aims to appropriate in the form of postulations and arguments the real determinations of the social reality. In the simplest model, the accumulation process in its crises and contradictions (to be identified in empirical investigation) set limits on both the intensity of development and forms of technologies. A more complex model which included the state was postulated to have a bearing on the ways in which the accumulation process affects the nature and intensity of technological development. Lastly, a considerably more complex model was included not for facilitating empirical investigation in this work, but rather for the purpose of showing the many complex connections between society and technology when given a new view of society (i.e., social formation) and its theoretical elaboration.
Chapter 5 conceptualizes technology. This activity of examining both the inner nature of technology and its inter-connections with other social processes is crucial if we are to consistently follow the thesis of the primacy of the relations of production detailed in Chapter 1. Although technology appears to us in its phenomenal form as an unmistakable thing, its production—and therefore, its very constitution on a society wide basis—rests on a structure of real relations and various social practices (such as political, ideological, scientific and so forth). In bringing out both the distinctiveness and the basis of unity between technological production versus scientific production we conceptualized technology as a practice. This conceptualization enabled us to: (1) overcome the persistent problem of where to locate technological knowledge in the social structure by showing that it is a specific form of practice subject to struggle and transformation in determinate directions, and (2) to more adequately identify in a more adequate way some of the relations and practices underlying the phenomenal forms. It followed from the first point that technology can never be understood as entirely functional to a particular social structure so long as the underlying social relations remain antagonistic. From the second point it is possible to specify some key aspects of the structure of a technological practice from which we can determine the nature of a phenomenal form.

Together, Chapters 4 and 5 involve closely related discussions on what is to be explained (technology) and what is to do the explaining (accumulation process). A couple points of clarification can be
advanced in order to grasp the significance of the theoretical dis­
sussion, the purpose it served in this dissertation and, consequently,  
the role of the empirical investigation presented in Chapter 6. First,  
the extended theoretical discussion represents (a) an attempt to drill  
through the appearances that can so easily tempt us to restrict attempts  
at explanation to relations among phenomenal forms and (b) an avoidance  
of idealist conceptions of society that obscure complex relations. Ta­
taken together, the persistent and consistent efforts to conceptualize  
the society-technology connection in terms of the relations disclosed  
by the accumulation process and in terms of the social-relational, yet  
retaining the distinctive content of technological practice, reflects  
these aims.

Second, in the reformulation of the problem and in the disclosure  
of the connection between accumulation and technology, the theoretical  
discussion is relatively self-contained. In other words, the validity  
of the theory developed here cannot be entirely dependent on empirical  
testing. The theoretical discussion is more an initial attempt to pose  
the problem in a new way and offer some conditions for further empiri­
cal investigations. The theoretical discussion has a direct bearing  
on the role of empirical investigation developed in Chapter 6. This  
investigation is only an attempt to build a meaningful linkage between  
the real relations described in the theoretical discussion and the pat­
tern of events that was captured in a brief historical analysis. This  
pattern of events is not meant to "reflect" real relations, but only
to show that such events make sense given the relations postulated in the theoretical discussions. Certainly a more rigorous investigation would be necessary for eliminating other possible explanations.

Chapter 6 explored some of the empirical implications to the theoretical Hypothesis 4.1, which stated:

Over years, changes in the forms of accumulation in Brazil lead to changes in the structural limitation that these forms impose on the creation of agricultural research technology promoted by state institutions.

Taking EMBRAPA (a Brazilian agricultural research organization) as our focus, we aimed first to locate EMBRAPA within the Brazilian social formation. Simply stated, the emergence of EMBRAPA and its on-going function is to be seen as an important state action in response to a progressive destabilizing of the traditional equilibrium among the various forms of accumulation in Brazil today. Due to an on-going capitalist expansion into agriculture, it was argued that the functionality of the agricultural sector to industrial expansion cannot be a permanent condition. Capital needs to expand, yet its expansion into agriculture undermines the subsistence sector that was so functional to the supply of cheap food to urban workers and hence enabling lower labor cost to urban industrialists.

Shaped by this overall and contradictory process, contradictions in EMBRAPA unfold as well. It is because EMBRAPA is not an external, neutral force, but rather an organization constituted by and implicated in the accumulation process that an examination of the events in EMBRAPA can give us an understanding of the relationship between accumulation and the generation of agricultural research technology.
Three events in EMBRAPA were highlighted: a technological package program, the graduate training program and the reformulation of the model of agricultural research. The details of each of these events were presented to indicate that the contradictory forms of accumulation in Brazil have situated limits, imposed constraints and set possibilities for the creation of agricultural research technology. Based on the wide variety of commodities served, the technological package program was found to be extended to small and subsistence farmers. This gives some support to the idea that (due to the particular set of contradictions) a variety of forms of technology not strictly reproductive of capitalist accumulation are, nevertheless, within the limits imposed.

In an effort to push technological knowledge beyond its known limits, EMBRAPA invested heavily in a graduate training program. Higher level degrees among technicians in EMBRAPA were found to increase by leaps and bounds. This increased training is believed to make researchers more responsive to farmers pressing for the development of new technologies. There is nothing in the data presented that would suggest that the increased training might function in favor of larger capital needs. Nevertheless, the increased training is an indication of an increase in the capacity to serve in this manner.

The replacement of a "diffuse" research model (DNPEA) with a concentrated one (EMBRAPA) was shown to have implications for research on technologies. The more concentrated model, in short, is likely to facilitate greater control over the research process. The precise
direction this control takes is, however, not so much a function of the "type" of research model in practice, but of the nature of the contradictions, of crises and of the balance of the class forces. This is not to say that the concentrated model is altogether indifferent to a given structure of productive relations, but only that the concentrated model will remain a site of struggle that may impose more constraints to the consolidation of interests which are non-reproductive of capital.

The empirical data we have found to be supportive of our theoretical arguments do not in any way prove only our postulations. Certainly other theories such as Parson's structural functionalism could offer an alternative interpretation of the data used here. What this study does show is that our major hypothesis is consistent with the data and that the logic of our theoretical arguments were capable of anticipating the empirical results.

Any work is subject to various constraints that are beyond the control of the researcher, such as fast approaching deadlines, and unavailable data. Obviously, this study must be viewed as only a first step in investigating the social structural determinations of agricultural research technology. In making this first step much effort has gone into a reformulation of the problem in order to explain the generation of agricultural research technology at the level of class relations structured by an accumulation process. As previously mentioned, this does not mean that explanations at levels other than at the social structural level can not be reasonably presented, but we nevertheless
argue (in Chapters 2, 3, 4 and 5) that an explanation at the social structural level is more fundamental, though rarely attempted in previous works. Future research aiming for an explanation of technology at the level of the social structure should focus on a number of issues which we have not been able to explore.

First, if we are to explain technology by a complex and contradictory process known as accumulation, it is indispensable to develop and use refined indicators of accumulation. Accumulation is not a variable, but a structure. This complex and contradictory structure does have effects, but those effects cannot be drawn into an index and simply called accumulation. Nevertheless, those effects need to be clearly identified because they are what press groups and classes together to give a determinate shape to technologies and what give a determinate rate to technological advance. Forms of accumulation vary synchronically in any given social formation as well as diachronically. In Brazil, accumulation occurs by the international corporations, the national bourgeoisie and petty bourgeoisie. Each of these categories may be broken down to show important differences, persistent conflicts, and so forth. For example, the national bourgeoisie consist of heavy and light industry. At any given time, accumulation can vary from one region to another or by commodity. Forms of accumulation can also be identified to vary over time. At one point in time the dominant form of accumulation in a social formation was petty capitalism whereas today in the same social
formation the dominant form is monopoly capital. As if those varied forms did not spell a complex enough task, various conjunctures may result from the contradiction inherent to accumulation. At a certain conjuncture, the advance of accumulation may cause a temporary alignment of the petty bourgeoisie with the working class and so on. But the complexity of the process is not to hide the fact that some relations and tendencies are more dominant than others and that it is the task of theory in a joint effort with empirical investigation to put aside the less important relations. This determination of the more fundamental relations must follow according to clearly stated reasoning, as developed by Marx, for example, relying less on formalistic accounts of the accumulation process.

Second, by conceptualizing technology within the constraints and possibilities of a theory based on the primacy of the relations over the forces of production, it is necessary to develop a full typology of technological forms that would reasonably follow from the structure of the social relations in production. As we have suggested in Chapter 5, technology is a result of specific choices made by groups but the options available are themselves shaped and limited by the social-material base. This study distinguished between research on domestic versus export crops. Future research will have to show what effect various technologies have on reproducing capitalist control, increasing efficiency and securing an ideological frame supportive of the technological changes. But where there are antagonistic
relations there remains the structural possibility of technologies that are non-reproductive of capitalist relations. Under what conditions might such technologies be possible? And what do such technologies embody that would enable an altogether different structure of social relations? These are the kinds of questions that will demand answers if we are to pull together a more adequate typology of technological forms.

Third, as we pointed out in Chapter 4, an investigation of the relationship between accumulation and agricultural research technology can hardly be carried on without examining the state's role in this relationship as well as its own effect in the creation of technologies. The state, by its political activity and by having its own structure, cannot be considered a direct expression of accumulation. It is at the level of the state that the question of the balance of class forces needs to be determined and despite the demands of accumulation, how the limits imposed by accumulation on agricultural research technology may be narrowed or widened depending on the composition of the state.

Fourth, future studies which postulate processes of structural limitation, selection and so forth must utilize greater methodological rigor than we were able to use. To fully substantiate the claim that the accumulation process sets limits on the creation of agricultural research technology, it would be necessary to demonstrate not only that certain forms are possible, but also why certain other forms are not possible (i.e., fall outside those limits). In future research, such a substantive demonstration should require a longer time span capable of covering more than one crisis period. This might give us some indication
of the technologies that are possible and those which are not under different dominant forms of accumulation.
APPENDIX 1

SIMPLE AND EXTENDED REPRODUCTION

It has been argued in the main part of this dissertation that as the driving force of capitalist development, the accumulation of capital is at the heart of the mechanisms of social reproduction. Studying the process of reproduction of the social capital at different levels of abstraction, Marx (1977b:392-523) identifies two types of reproduction: simple and extended reproduction. The simple reproduction model abstracts the capitalist's concern to expand his capital. It corresponds to a capitalist system that keeps its same size and proportions indefinitely. The total production of society is divided into two major departments (or sectors): Department I, which produces means of production, and Department II, which produces consumption goods (Marx, 1977b: 395). The reproduction schemas developed in Marx (1977b) highlight not only a "normal" and smooth functioning of the economic system within a rough environment of crises and recuperations, but they can function as an instrument to facilitate the analysis of what the Keynesians call the "circular flow of income," as well. Thus, in simple reproduction, we have:

Department I
\[ C_1 + V_1 + S_1 = P_1 \]

Department II
\[ C_2 + V_2 + S_2 = P_2 \]
where: \( C_1 \) and \( C_2 \) = the constant capital of Department I and Department II, respectively

\( V_1 \) and \( V_2 \) = the variable capital of Department I and Department II, respectively

\( S_1 \) and \( S_2 \) = the surplus value extracted from Department I and Department II, respectively

\( P_1 \) and \( P_2 \) = the product measured in value of Department I and Department II, respectively

As an abstraction, the conditions of simple production and reproduction imply that the constant capital used up in both departments is precisely equal to the output of Department I, i.e., \( C_1 + C_2 = C_1 + V_1 + S_1 = P_1 \). Within the same logic, the simple production model also implies that the consumption of capitalists and works of Department I and Department II together is equal to the output of Department II, i.e., \( V_1 + S_1 + V_2 + S_2 = C_2 + V_2 + S_2 = P_2 \). \( P_1 \) and \( P_2 \) form the aggregate social supply of commodities. Thus, derived from the two equations above, the basic condition of simple reproduction can be expressed as \( C_2 = V_1 + S_1 \), i.e., the assumption behind this abstract model is the absence of capital accumulation within the scheme of simple reproduction.

The extended reproduction (capital accumulation) model (Marx, 1977b:489-523) drops the assumption of the simple reproduction (non-capital accumulation). Thus, we have:
Department I

\[ C_i + V_i + S_{cl} + S_{acl1} + S_{avl} + S_{acl} = P_1 \]

Department II

\[ C_2 + V_2 + S_{c2} + S_{ac2} + S_{av2} + S_{ac2} = P_2 \]

where the new elements are:

- \( S_c \) = amount spent on consumption which is just sufficient to maintain capitalists' consumption at the level of the preceding period
- \( S_{ac} \) = increment of consumption
- \( S_{av} \) = accumulation which serves to increase variable capital
- \( S_{ac} \) = accumulation which serves to buy additional constant capital

The summation \( S_{av} + S_{ac} \) represents the concept of accumulation for Marx.

(Figure and symbols were heavily drawn from Sweezy, 1942:163.)

In spite of being more cumbersome than that of simple reproduction, the equilibrium condition in the extended reproduction scheme keeps a basic structural similarity. In extended reproduction (accumulation of capital), the constant capital and the accumulation necessary to buy additional constant capital of Department I and Department II is equal to the output of Department I, i.e.,

\[ C_1 + S_{acl1} + C_2 + S_{ac2} = C_1 + V_1 + S_{cl} + S_{acl} + S_{avl} + S_{acl}. \]

The first part of the equation represents the demand, the second part the supply. On the other side, the consumption of capitalists and workers plus the increment of consumption and the accumulation necessary
to increase variable capital of Department I and Department II is equal to the output of Department II, so that

\[ V_1 + S_{c1} + S_{a1} + V_2 + S_{c2} + S_{a2} + V_2 + S_{c2} + S_{a2} + S_{av2} = C_2 + V_2 + S_{c2} + S_{a2} + S_{av2} + S_{ac2} \]

The first part of the equation represents the demand, the second part the supply. From both equations the basic condition of equilibrium of extended reproduction (accumulation of capital) is derived and takes the following form:

\[ C_2 + S_{ac2} = V_1 + S_{c1} + S_{a1} + S_{av2}. \]

Since expanded reproduction consists of the accumulation of both constant and variable capital, the rate of accumulation is represented by \( S_{ac} + S_C + S_{aC} + S_{av} \), or, for the sake of simplicity, by \( \frac{\Delta C + \Delta V}{C + V} \), where \( \Delta C + \Delta V = S \). This accumulation of capital is at the same time an extension of capitalist relations. A necessary condition of the reproduction of capital is the reproduction of those capitalist relations. The maximum possible rate of accumulation (when all of \( S \) is transformed into additional \( C \) and \( V \)) is given by the value rate of profit (\( r \)), \( \frac{S}{C + V} \) (for a more complete treatment of the rate of profit, see Hodgson, 1974). To expand \( C + V \), i.e., to obtain \( \Delta C + \Delta V \), implies an extension of the capital-labor relation. This suggests that \( \Delta C + \Delta V \) does not only represent a study of the physical quantities involved in the phenomenon, but fundamentally provides a means to access the social
content of that process. Accumulation means a transformation in relation and not exclusively a transformation of thing. To restrict the study to physical quantities C + V is to concentrate only on the visible reality of the process (see Chapter 3 for more details on the double reality of a phenomenon).
APPENDIX 2

TRANSFORMATION OF THE ORIGINAL FORMULA OF THE RATE OF PROFIT \( r \)

Given that,

\[ \begin{align*}
C &= \text{the value of the constant capital} \\
V &= \text{the value of the variable capital} \\
S &= \text{the value of the surplus product produced by workers} \\
V+S &= \text{the total amount of living labor time used in production} \\
Q &= \text{the organic composition of capital} = \frac{C}{V+S} \\
e &= \text{the rate of exploitation} = \frac{S}{V}, \text{ and} \\
r &= \text{the rate of profit} = \frac{S}{C+V},
\end{align*} \]

we can develop the rate of profit \( r \) in the following way:

\[
\begin{align*}
r &= \frac{S}{C+V} = \frac{S/(V+S)}{(C+V)/(V+S)} = \frac{S/(V+S)}{C+V+S} = \frac{S/(V+S)}{C+V+S(1+\frac{V}{C})} \\
&= \frac{SV}{(V+S) V} = \frac{S/V}{(V+S)/V} = \frac{S/V}{Q + \frac{C}{V+S} V} = \frac{S/V}{Q + \frac{V}{V+S}} \\
&= \frac{S/V}{1 + (S/V)} = \frac{(1+e)}{Q + \frac{1}{(V+S)/V}} = \frac{e/(1+e)}{Q + 1} = \frac{e/(1+e)}{Q + 1} = \frac{e}{Q + 1} + \frac{1}{1+e} \\
&= \frac{[e/(1+e)] \cdot (1+e)}{[Q + 1/(1+e)] \cdot (1+e)} = \frac{e}{Q(1+e) + 1}
\end{align*}
\]
APPENDIX 3

DOMESTIC PRICE INDEX AND CONVERSION FACTORS, 1973-1979

Base 1977 = 100

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<tr>
<th>Year</th>
<th>Domestic Price Index</th>
<th>Conversion Factor</th>
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<tbody>
<tr>
<td>1973</td>
<td>30.1611</td>
<td>3.3155</td>
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<tr>
<td>1974</td>
<td>38.8136</td>
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<td>1975</td>
<td>49.6333</td>
<td>2.0148</td>
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<td>1976</td>
<td>70.1003</td>
<td>1.4265</td>
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<tr>
<td>1977</td>
<td>100.0000</td>
<td>1.0000</td>
</tr>
<tr>
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<td>138.7000</td>
<td>.7210</td>
</tr>
<tr>
<td>1979</td>
<td>213.5000</td>
<td>.4684</td>
</tr>
</tbody>
</table>


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