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DID THE GREEN REVOLUTION CONCENTRATE INCOMES? A QUANTITIVE SUTDY OF RESEARCH REPORTS

*1. Introduction**

Disparate findings on the influence of the rapid introduction of high-yield varieties 25 years after their first implementation provide no consensus from the academic community about the income distribution effects of this technological strategy. There is no adequate explanation for the disparate conclusions. This analysis attempts to determine the usefulness of the existing literature for identifying defensible generalizations about the income effects of the new technology and for discerning the causes for the different interpretations. What on balance do we know from the 25-year record of research on the effects on income distribution of the rapid introduction of the high-yield varieties (HYV) package of technology in Third World agriculture?

The procedure employed here is unusual in the social and economic evaluation of literature on a topic. I am employing the results of research reports as data for testing hypotheses concerning the correlates of the Green Revolution technology with the economic and social changes in the regions where it has been employed. The methodology is similar to that used by John Walton (1970) to evaluate the body of research on community power structure. In this type of evaluation the tests of relationships are indirect when dealing with propositions about the effects of the Green Revolution but direct and entirely appropriate when dealing with propositions concerning the accumulated research. Although I would like to be able to make definitive statements about the effects of the new technology on income in Third World agriculture, this method permits me only to make inferences; propositions concerning previous research are, however, subject to direct testing.

A computer search of the social science literature on the effects of the Green Revolution was carried out for the period 1970 to 1989. The data base searched was that maintained by the British Commonwealth Agricultural Bureau as the World Agricultural Economics and Rural Sociology Abstracts. Although the abstracting service attempts to control the world literature in its fields, it does not include all published items for all regions of the world. For the geographic areas of South and Southeast Asia, where the Green Revolution had its greatest effect, I consider this data base to have particularly good coverage. A total of 324 journal articles, books, and technical reports were identified that treated the economic, political, and social effects of the new technology.[1] Of these, 307 studies were located and could be included in

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[1] These studies are not listed in the literature cited. Readers who would like the complete listing may request a photocopy from the author.

this research. Each report has been treated as an observation and the studies included, though an almost complete universe for the data base studied, are considered as a sample of the total universe of all studies on the consequences of the Green Revolution. A standard summary guide was prepared, and trained readers recorded for each article information of relevance to the study. In addition to identifying the research report, the author, the location of the study, the year of publication, and other descriptive elements, four areas of substantive relevance were explored: production and productivity growth; adoption; employment; and income and wealth concentration. Each article was read for content by an assistant and by the author of this overview. The author alone coded the resulting summary sheets for the computer analysis.

The purpose of including the full body of literature was to provide the most systematic coverage possible, and to avoid the citation of a few selected references to illustrate a point as is done in a conventional literature review. Some readers might object to giving equal weight in the evaluation to all studies; indeed there is disagreement about whether or not a priori judgements about the quality of research should be used to exclude studies from this kind of analytical review. The arguments for both sides have been brought together fairly well in an exchange between Hans Eysenck (1978) and Gene V. Glass and Mary Lee Smith (1978). In criticizing a review of over 300 studies on psychotherapy by Smith and Glass (1977) Eysenck says, "A mass of reports —good, bad, and indifferent— are fed into the computer in the hope that people will cease caring about the quality of the material on which the conclusions are based [...] only better designed experiments than those in the literature can bring better understanding of the points raised." (p. 517).

In their response, and in other related statements, Glass and Smith argue that one's next study ought "to be well designed because one wants to believe its findings and plan subsequent studies on the basis of them. But once the study is completed and its findings join those of dozens of other studies on the same topic, the sophistication and validity of the study design becomes an entirely different matter" (Glass and Smith, 1978, p. 518). Elsewhere Glass (1976) argues against discarding reports because of "design or analysis deficiencies of all but a few studies —those remaining frequently being one's own work or that of one's students or friends— and then [to] advance the one or two 'acceptable' studies as the truth of the matter" (p. 4). He continues with the assertion that studies with "design and analysis flaws may still be valid" (p. 4). Discarding would lead to a "profligate dismissal of hundreds of findings" (Glass and Smith, 1978, p. 517). Rounding out their argument, in a broader overview of their work on integrating research results, they concluded that study quality is "an empirical a posteriori question, not an a priori matter of opinion or judgement used in excluding large numbers of studies from consideration" (Glass, McGaw and Smith, 1981, p. 222). In this review of Green Revolution literature I have chosen to follow this lead by including the full set of identified studies and then allow methodological and structural characteristics of the studies to be associated with their findings.

Given the eclectic character of the methodology used in these studies (historical, didactic, comparative, analytical), all of the variables were defined either as nominal,

that is, defined within exhaustive and mutually exclusive categories, or as interval variables, with unambiguous categories which are also mutually exclusive. This systematic characterization of each study permitted the construction of tables that show the distributions of descriptive and substantive characteristics of social science literature on the Green Revolution and the testing of hypotheses concerning possible relationships among the measured variables.

As the results of this overview will show, the literature indicates increasing disparities in income among farmers following the introduction of the new technology, both interregional and even in the favored zones (intraregional). Because of the inconsistencies between these results and the predominant policy justifications, the data set will be used to test several hypotheses as to why there may be contradictions between overall research results and policy implementation. But before looking at the results of this quantitative inquiry let us begin with a recapitulation of the recent history of the events under review.

2. The Green Revolution as a Strategy for Development

Following a series of bad agricultural years, in the mid-1960s both India and Pakistan realized that they had serious agricultural production problems. The possibility of famine in the subcontinent led many, both within the region and without, to the tentative conclusion that India, in particular, had lost the capacity to feed itself. Strong policy changes were needed. A solution was perceived in the widely recognized success of the high-yield varieties used to increase Mexico's wheat production. The Mexican wheats had already been tested for adaptability in both the Pakistan and Indian Punjab regions, where, under favorable conditions, the exotic seeds demonstrated the capacity to produce yields two to three times higher than those obtained by farmers with their traditional husbandry. Mexican seed wheat was shipped to India and Pakistan in 1965-66 to plant several hundred thousand hectares during the 1966-67 production season (Dalrymple, 1969).

The "miracle" seeds performed as expected, and new hope was born for agriculture in the subcontinent. Farmers accepted the new and superior production technology, and government policy facilitated its use. Within five years high-yield varieties of wheat were planted on almost 10 million hectares in India, about 40 percent of all wheat plantings; higher yields and greater profitability encouraged expanded wheat acreage, more than doubling wheat production. India shifted from an important importer of wheat to self-sufficiency. More important still, modern agricultural production processes were perceived as providing the path for sustained agricultural growth, and the pessimism concerning the ability of countries to feed themselves subsided. The scientific method applied to the practical problems of production agriculture resulted in abundance —a "Green Revolution" had occurred.

This improved agricultural technology involved several critical elements: improved varieties (especially for wheat, rice, and to a certain degree maize) with an

inherently higher yield response to chemical fertilization, irrigation and biochemical programs for disease, insect and weed control (Brown, 1970; Dalrymple, 1969; Stakman, Bradfield and Mangelsdorf, 1967; Poleman and Freebairn, 1973). The importance of these events was confirmed when the 1970 Nobel Peace Prize was awarded to Norman Borlaug, the chief wheat producer in the development of the technology and the guiding force in its implementation to solve the problems of global hunger.

When the introduction of high-yielding varieties became viewed more as a strategy for successful agricultural and rural development than as a straightforward agronomic technique, the broad implications of such a strategy were questioned. Within five years of the first plantings of the new seeds in India, critics, especially social scientists, expressed concern about the economic, social, political, and ecological effects of the program. Strong defenders of the new approach, mostly agriculturists and some economists, responded that the early critics were mistaken. The arguments centered mainly on the equity consequences of the rapid introduction of the improved technology, but some concern for its ecological and biological consequences was expressed.

The early critics of the HYV programs argued that the new technology was inherently selective because it was aimed at the most advantaged agricultural regions. Wheat and rice were the two most successful interventions. The wheat technology was for irrigated plantings, the predominant method in the subcontinent but a small fraction of the world's wheat-growing domain. Rice technology was also for areas with effective water control, estimated to represent about one-fifth of the rice-growing regions in South and Southeast Asia (Barker and Mangahas, 1970). Because many regions were not suited for the HYV technology, the Green Revolution contributed to a considerable change in interregional income distribution. Critics argued that the new technology would benefit producers who controlled the optimal production environments —good quality soil, access to irrigation facilities, and locations favorable to markets because of cheap transportation, communication, and other linkages to urban centers. Producers without access to such environments would not benefit; rather, they would lose competitiveness and be both absolutely and relatively disadvantaged compared to producers in the favored zones. Interregional income differences, it was argued, would be exacerbated to the disadvantage of well over three-fourths of the poorer farmers in the rice regions of the developing world (FAO 1973, Freebairn, 1973).

The critics argued that even in the favorable production environments the technology was inherently biased toward larger and more advantaged cultivators and landholders because access to the improved technology is greater for those better linked to government and private information sources; access to subsidized inputs is often related to social and political status; credit, usually necessary for implementation of the new technology's increased requirement of purchased inputs, is dependent on landholding, both the possession of legal title (as contrasted to tenancy) and the greater security of larger than smaller holdings. They further argued that landowners would benefit over tenants and laborers with the surplus accruing in direct proportion to the area of land owned. Cultivators as a class might gain, but landless laborers would have

few claims on the increased productivity. Hours worked per area of arable land might increase because of the greater intensity of production, but the hours per ton of final product would decrease. When supply and demand reached equilibrium, there would be a stagnation in total labor employed, albeit at a higher level than that before the change. In addition, if the new technology was highly profitable, capital (tractors, harvesting machines, threshers, and so on) would be introduced into the production process, which would reduce labor use and induce changes in the traditional laborer/cultivator relationship to the disadvantage of day laborers. Some also held that cultivator-owners would tend to use some of their newfound profits to consolidate their relative and absolute gains by forcing off tenants, substituting capital for labor, and lobbying for input and price subsidies to their increasingly productive segment of the agricultural sector (Feder, 1975; Frankel, 1971 and 1973; Freebairn, 1973; Ladejinsky, 1977).

The counter position was also clearly delineated. The fundamental issue, it was argued, is that rapid population growth requires more production in a food-short world. Although this Malthusian formulation was the overriding imperative in much of the argument for the HYV strategy, strong spread effects were expected from the technology. The HYV technology was not expected to lead to a more unjust and inequitable world. A basic element in the argument was that the biological nature of the technology makes it scale-neutral —the inputs required to place it in operation are divisible into sufficiently small purchase units that the full package is available to all producers whatever the scale of their operation. Seed grain, fertilizer, water, and pesticides are easily divisible inputs. It was further argued that cultivators of all sized farms are motivated by economic returns. If offered a superior production system that provides the opportunity to earn higher rewards for their capital, land, and work effort, farmers the world over will rapidly adopt the new system. Benefits would spread to landless workers, it was argued, through the increased labor requirements per hectare planted to the more labor-intense technology and possibly through more intensive cultivation. (Borlaug, 1972; Herdt and Capule, 1983; Hayami and Ruttan, 1985; Schultz, 1964.)

Although not formulated as elegantly in the early days of the controversy as it was later, there was an underlying belief that more efficient production processes would benefit consumers because rapidly increasing basic food crop productivity would result in lower food costs. Food can represent a high fraction of the consumption expenditures of workers in lower-income countries, and stabilization or reduction in its real cost can greatly benefit this population if nominal wages remain constant and food prices drop. But, if wages are at a socially defined subsistence level and there are large numbers of potential entrants to the work force, the reduced costs of wage goods may allow nominal wages to drop, thus permitting real wages to remain constant with wage earners no better off than before the cost-reducing agricultural innovation was introduced. Corollary opportunity could obtain, however. A real reduction in prices of wage goods could permit the expansion of labor-intensive enterprises in contrast to the emphasis on capital intensive industries where the wages bill is of secondary importance. The lower-cost wage goods interpretation finds the multiplier through a consumption effect and derives from the expansion of agricultural output and investment, a view that stands in

apposition to the more generally held limited investment linkages associated with agricultural investments (Hirschman, 1958, Mellor, 1976).

A couple of related non-distributional factors associated with the new technologies are important, although they will not be reviewed in detail in this analysis. Ecological and biological factors received little serious consideration in the early discussions of the pros and cons of the HYV program for agricultural and rural development. Three elements were to find some resonance in later discussions. First, the introduction of varieties with a limited genetic base risked exposing great areas of basic food crops to a widespread disease infestation with possible catastrophic reductions in production. In response, it was argued that careful monitoring of varietal disease resistance prevents disastrous epidemics. The widespread adoption of improved varieties reduces genetic diversity, making it essential that the land races of important grains be preserved through alternative mechanisms (Wade, 1974). A second concern, particularly following the oil crisis of 1973, was that the new technology was highly dependent on fossil fuel energy sources. It was feared that the rising relative cost of petroleum-based inputs relative to the price of grains would make the new agricultural production system nonviable and that the finite supplies of fuels would make the new technology unsustainable (Loomis, 1976; Pimentel *et al.*, 1975). A third related reservation was that the intensive use of fertilizers, pesticides, and weedicides would cause pollution of natural resources and environmental degradation and would endanger the health and well-being of the handlers and users of the biochemical inputs. (Carson, 1962; Wade, 1974; Wright, 1990.)

These arguments appeared largely as theoretical formulations in the late 1960s and early 1970s when there was still little empirical evidence to support any position. Over the years, notwithstanding an increasing body of research results, the division in argument has continued with little consensus or "conventional wisdom" surfacing at the intellectual level. Concern for broad participation in development continued throughout the 1970s and 1980s, and academics defended both sides of the argument as to whether the Green Revolution would have positive direct and indirect effects in creating more equitable distribution of farmers' incomes and alleviating the acute poverty. Byres (1981), Cleaver (1972), Farmer (1977), Griffin (1974), Pearse (1980), and Wharton (1969) were among those who doubted that the technology, as it was being implemented, would have strong spread effects. Equally strong arguments led by Borlaug (1972), Hayami and Ruttan (1985), Hazell and Ramasamy (1991), Mellor (1975), and Schultz (1964), justified optimism on the issue. It is doubtful that at the policy level of any operating unit, either national or international, anyone felt the new technological strategy would be anything but a positive force toward broadly based agricultural and rural development. This policy position was reinforced by the institutionalization of an international structure in support of the development and sharing of improved genetic materials and techniques for agricultural research, this being an important part of the mandate for the Consultative Group on International Agricultural Research, a self-administering unit which coordinates financial support to 18 international agricultural, resource and food related research institutes. In recent years it has

channeled about $250 million per year from some 40 donor organizations (Von der Osten-Sacken, 1992). Although at the intellectual level the technological strategy has been questioned, at the operating level the implementation of the program has been largely unquestioned. However, it should be recognized that in the early years these agencies had to act without the benefit of a significant research record.

The fundamental issue for those who have questioned the technological strategy has not been whether higher productivity in agriculture is desirable —the potential social benefits from rapidly increasing productivity are obvious. Rather they were concerned about participation in the benefits from technical progress by all classes of cultivators and farm workers, and argued that structural reforms were important to that end. We should remember that throughout the 1950s and 1960s not only was there a strong intellectual call for improved institutional arrangements, most commonly land reform, but that the evidence supporting institutional reform as an instrument for increasing economic growth was fairly strong (Berry and Cline, 1979). The notion that agrarian reforms were needed was accepted by progressive groups in industry, finance, and government in many countries. And, although others objected, some partial reform programs were implemented and were fairly successful; overall grain production in the Third World increased during the 1950s and until the mid-1960s at an annual growth rate of more than 3.0 percent (FAO, 1967). In the 1970s, with the extraordinary growth of wheat production in India, the need to continue reform programs that attacked structural rigidities appeared to be less pressing. Agriculture could be made productive through technical improvements, avoiding the tough political challenges of reform policies. No established interests argued against improved seeds, water development, fertilizer usage, government subsidies, and improvements in market facilities. It was assumed that production bottlenecks could be eliminated through technological methods, and that the general economy could build on agricultural successes.

As a follow up to this background, the next section reviews the accumulated research, summarizes the results reported, and specifies some of the possible causes of the contradictions found in the literature.

3. What the Research Studies Show

In this evaluation, interest centers on the authors' conclusions on the issue of distribution of benefits to producers —both interregional and interfarmer. The measure being used is equality, and that is not, of course, the only one which could be used. It can be argued that absolute gains by definable groups is equally valid. A Pareto-optimum test for allocative efficiency is that no adjustment can be made which would make some person(s) better off without at the same time making another (others) worse off. Thus all persons are at least equal to the situation obtained before any adjustments while some would be better off (see Page's translation from the *Manuel D'Economie Politique*, 1968, p. 382). In this context, it can be argued that as long as everyone is better off, or at least not worse off, the exact distribution is of lesser importance.

Table 1
Distributions of Authors' Conclusions of the Income Effects of the Introduction of HYV Technology, Green Revolution Research Review 1970-1989 (n = 307) (percentages)

A. Authors' Conclusions on Changes in Farmers' Income Concentrations during Green Revolution Period		*B. Authors' Conclusions on Changes in Interregional Income Differences in Post-vs. pre-Green Revolution Period*	
Concentrations	*Frequency*	*Differences*	*Frequency*
Increased	39.7	Increased	33.6
Decreased	3.9	Decreased	1.3
Unchanged	8.5	Unchanged	2.0
No conclusion	47.9	No conclusion	63.2

Although the requirement that no segment be absolutely disadvantaged is a strong requirement.

John Rawls in his *Theory of Justice* (1971), defines the distinction between the Pareto-optimum formulation and his own concept of justice as fairness. Among other aspects, he argues that inequalities can be accepted within a concept of justice only if they are a necessary component of improving the well-being of the least advantaged (pp. 14-15 and 60-65). This is a stronger specification than many are willing to incorporate in their work and is based on the concept of justice as a prerequisite to the formation and maintenance of a viable human community based on a scheme of social cooperation. Without requiring so strong an equity consideration as that specified by Rawls, the studies in this sample were coded for the direction of greater or lesser equality. It is this concept which has been an important component of the research on the Green Revolution experience, and the present is a study of the accumulated research on this topic.

A quick perusal of the data given in Table 1 indicates that the authors' conclusions on the distributional effects of the Green Revolution do not correspond to the predominant assumptions guiding programs in agricultural agencies. The research findings contradict the view that the new technology has broad spread effects. Over one-third of authors concluded that the Green Revolution strategy exacerbated income differences both within and between regions; less than 4 percent concluded that the technology narrowed such differences. Although few investigators asserted that the technology had no effect on interregional differences, slightly more than 8 percent concluded that farmer-level (intraregional) income distributions were left unaffected. In both sets of conclusions, the interpretation is complicated by the many studies half or more of whose authors either chose not to address this issue or whose emphasis precluded drawing conclusions. There is little support for the proposition that social science research has found that the implementation of the HYVs technology had positive spread effects.

Nor have research results changed between the earliest studies and those done

more recently. The data enables us to test a pair of hypotheses which derive from assertions made in the literature. This data set is the sample of the entire body of social science research on the Green Revolution; it has sufficient observations to permit formulating conditional associations among relevant variables. Perhaps the first, and in many respects the easiest, illustration is to review the proposition forwarded by Pinstrup-Anderson and Hazell (1985, p. 8): "A number of early studies [...] concluded that the rural poor did not receive their fair share of the generated benefits [...] recent studies have produced a sizable body of evidence which proves beyond a reasonable doubt that they are wrong."

This proposition can be tested by hypothesizing that there were no significant differences in the distributions of authors' conclusions concerning changes in interregional producers' income levels for publications issued in the early, middle, and later years. A second and related null hypothesis holds that there were no significant differences in the distributions of authors' conclusions concerning changes in farmers' income distributions within regions during the Green Revolution years, again consulting publications issued in different time periods.

Pinstrup-Anderson's and Hazell's assertion may refer to the results from repeated studies on the same areas and at sequential stages in the historical course of the implementation of the Green Revolution technology, although this is not clearly expressed. Implicitly this is what a temporal change explanation would require. The procedures which I have followed and the body of studies included in the analysis do not permit me to give such an assurance. Time here is determined by the date of publication, and while studies tend to concentrate on the areas of maximum impact of the rice/wheat improved technologies, the results of these contingency relationships need to be interpreted with some caution because of the possibly less than perfect relationship between the actual and the theoretically ideal specification.

The Pinstrup-Anderson and Hazell proposition refers to benefits for both producers and consumers, although it is clear from the context that it applies to the distribution of producer-level benefits which is the focus of this evaluation. The results of the contingency analyses are given in Table 2. There are no marked differences in the distributions of authors' conclusions on the between-farmer and interregional income differences among studies carried out in the early, intermediate, and later periods of the new technology. This observation is supported by a lack of statistical significance at the 0.10 level of confidence using the chi-square distribution.

Not only does this material raise serious doubts about the strong conclusions of Pinstrup-Anderson and Hazell, but it leaves the conundrum of substantial disagreement among both practitioners and academics on the distributive effects of the rapid introduction of the HYV technology without so neat an explanation as the temporal one suggests. We are left with two related but different uncertainties. What have been the income effects of the Green Revolution on distinct classes of agriculturalists and on different regions? And what does the literature say about these effects? Probably it needs to be repeated that this study addresses only the second of these uncertainties. An analysis of the literature can only tell us what authors of the studies have been

Table 2
Distributions of Authors' Conclusions on Income Changes During The Green Revolution Period By Year of Publication, 1970-1989 (n = 307)
(percentage)

A. Farmer-Level Income Concentration (Intraregional)			
Changes in Concentration	*1970-1976*	*1977-1982*	*1983-1989*
Increased	38.6	44.6	36.6
Decreased	4.6	3.6	2.8
Unchanged	7.2	14.5	4.2
Not specified	49.7	37.3	56.3
n	(153)	(83)	(71)
B. Interregional Income Difference			
Changes in Income	*1970-1976*	*1977-1982*	*1983-1989*
Increased	34.6	36.1	28.2
Decreased	1.3	2.4	0
Unchanged	1.3	3.6	1.4
Not specified	62.8	57.8	70.4
n	(153)	(83)	(71)

Chi-square tests for differences showed no significance at the 0.10 level of confidence.

reporting; it cannot evaluate what actually happened on the farms and in the regions of Third World agriculture. In this sense the enterprise has an academic orientation and raises questions about research. What do cumulative research results tell us about certain themes, in this instance the distributional consequences of the rapid introduction of an improved technology in agriculture? Are there explanations for strong differences in the interpretations of the same basic phenomena and research results?

Because only a few authors concluded that the new technology would decrease interregional income differences, only the changes in concentrations of farmer-level income distributions within regions will be considered. As shown in Table 1, 40 percent of the authors concluded that income distribution among farmers became more concentrated during the Green Revolution period as compared with the previous period, 4 percent concluded that income concentration decreased, and 8 percent that it was unchanged; almost half of the authors did not specify conclusions on the issue. A possible explanation for the disparate interpretation of the research is that some characteristic or set of characteristics might be associated with the conclusions that can be drawn from the research. Such items as the regional origin of the author, the location of the study area, the methodology used, and the geographic extension of the area covered by the study might alone, or in combination, be associated with differential distributions of the authors' conclusions.

In formalistic manner the following hypotheses are specified, each to be tested using the data set from the literature here reviewed:

1) Authors of different regional origins do not differ in their conclusions as to whether farmers' income distribution became more concentrated during the Green Revolution period. The general relationship may be further specified by controlling for methodological approach, location of study, and geographic extension of the study area.

2) Studies using different methodological approaches do not differ in their authors' conclusions about changes in concentrations of farmers' income distribution during the Green Revolution period. The general relationship may be further tested by controlling the regional origin of author, location of the study, and geographic extension of the study area.

3) There are no differences in the distribution of authors' conclusions on changes in farmers' income distribution concentrations during the Green Revolution period between geographic locations of the study area. The general relationship may be further tested by controlling the regional origin of author, methodological approach, and geographic extension of the study area.

4) There are no differences in the distribution of authors' conclusions on changes in farmer-level income distribution concentration during the Green Revolution period among studies with different geographic extension of study area. Again, the general relationship may be further tested by controlling for regional origin of the author, methodological approach, and location of the study.

The results of these tests are given in Tables 3-6. A word of explanation in interpreting these tables may be in order. For Tables 3-6 the upper panels represent the zero-order contingency relationships, or what I sometimes refer to as the general relationships between authors' conclusions on income inequality and the four hypothesized structural or methodological characteristics which might explain the differences. The lower panels, which show the relationships with each of the other variables as a control, have been simplified by truncating the distributions and just reporting the proportion of studies in the cells for increased inequality. The results may be interpreted as a dichotomized representation —the proportion of studies with conclusions that inequality increased *versus* the others combined. The discussion will cover first the general relationship (that is, the data in the upper panels of the four tables) and then the impact which the introduction of the control variables have on the analysis.

In each instance the "zero order" relationships resulted in rejection of the generalized null hypotheses. Indeed, there are differences in the distributions of authors' conclusions concerning the effects of the new technology on farmer-level income differences as a function of each variable hypothesized. As shown in Table 3, a considerably higher proportion (54 percent *vs.* 30 percent) of Western developed country and other non-Asian authors concluded that there were increasing disparities in farmers' incomes during the Green Revolution period than did Asian authors.

Table 3
Relationship between Authors' Conclusions on Changes in Inequalities of Farmer-Level Income during the Green Revolution Period and the Regional Identification of the Author, Research Review 1970-1989 (n = 307) (percentages)

Authors' Conclusions on Income Inequality	*Regional Origin of Author**	
	Asian Authors	*Non-Asian Authors*
Increased	30.0	53.5
Decreased	6.1	0.8
Unchanged	7.8	9.4
Not evaluated	56.1	36.2
n	(180)	(127)

Percentage of authors who found increased inequality when controlling successively for:

Control 1: Methodological Characterization

Conclusions on Income Inequality⁺	*Asian Authors*			*Non-Asian Authors*		
	*Case**	*Analytical**	*Essay**	*Case**	*Analytical**	*Essay**
Increased	30.6	17.5	39.5	33.3	51.9	60.5

Control 2: Geographic Location of Study Area

Conclusions on Income Inequality⁺	*Asian Authors*		*Non-Asian Authors*	
	India/Philippines	*All other**	*India/Philippines*	*All other**
Increased	26.7	38.8	34.0	65.0

Control 3: Geographic Extension of Study Area

Conclusions on Income Inequality⁺	*Asian Authors*			*Non-Asian Authors*		
	*Micro**	*Country**	*Macro**	*Micro**	*Country**	*Macro**
Increased	25.6	33.3	37.5	35.0	60.0	64.9

* Differences between the distributions are significant at 0.05 or higher levels of confidence.
⁺ Distributions have been truncated, with only the cells for increased inequality being reported.

Table 4
Relationship between Authors' Conclusions on Changes in Inequalities of Farmer-level Income during the Green Revolution Period and the Methodological Characterization of the Study, Research Review 1970-1989 (n = 307) (percentages)

Authors' Conclusions on Income Inequality	*Characterization of the Methodology**		
	Case Study	*Analytical*	*Essay*
Increased	31.7	27.8	49.7
Decreased	8.3	6.7	0.6
Unchanged	28.3	3.3	3.8
Not evaluated	31.6	62.2	45.9
n	(60)	(90)	(157)

Percentage of authors who found increased inequality when controlling successively for:

Control 1: Regional Identification of Author

Conclusions on Income Inequality⁺	*Case Study*		*Analytical*		*Essay*	
	*Asian**	*Non Asian**	*Asian**	*Non Asian**	*Asian**	*Non Asian**
Increased	30.6	33.3	17.5	51.9	39.5	60.5

Control 2: Geographic Location of Study Area

Conclusions on Income Inequality⁺	*Case Study*		*Analytical*		*Essay*	
	*India/ Philippines**	*All Other**	*India/ Philippines**	*All Other**	*India/ Philippines**	*All Other**
Increased	20.0	48.0	16.4	51.7	41.5	58.7

Control 3: Geographic Extension of Study Area

Conclusions on Income Inequality⁺	*Case Study*			*Analytical*			*Essay*		
	*Micro**	*Country*	*Macro*	*Micro**	*Country**	*Macro*	*Micro**	*Country**	*Macro*
Increased	33.9	a	a	18.6	29.3	83.3	34.8	50.0	57.9

[a] Too few observations in these cells for evaluation.

* Differences between the distributions are significant at 0.05 or higher levels of confidence.

⁺ Distributions have been truncated, with only the cells for increased inequality being reported.

Table 5
Relationship between Authors' Conclusions on Changes in Inequalities in Farmer-level Income during the Green Revolution and the Geographic Location of the Study, Research Review 1970-1989 (n = 307)
(percentages)

	*Geographic Location of the Study**	
Authors' Conclusions on Income Inequality	*India/Philippines*	*All Other*
Increased	28.7	55.0
Decreased	4.5	3.1
Unchanged	7.9	9.3
Not evaluated	58.9	32.6
n	(178)	(129)

Percentage of authors who found increased inequality when controlling successively for:

Control 1: Regional Identification of Author

	Studies in India/Philippines		*All Other Studies Location*	
Conclusions on Income Inequality+	*Asian*	*Non-Asian**	*Asian*	*Non-Asian**
Increased	26.7	34.0	38.8	65.0

Control 2: Methodological Characterization

	Studies in India/Philippines			*All Other Studies Location*		
Conclusions on Income Inequality+	*Case Study*	*Analytical**	*Essay**	*Case Study*	*Analytical**	*Essay**
Increased	20.0	16.4	41.5	48.0	51.7	58.7

Control 3: Geographic Extension of Study Area

	Studies in India/Philippines			*All Other Studies Location*		
Conclusions on Income Inequality+	*Micro**	*Country**	*Macro*	*Micro**	*Country**	*Macro*
Increased	16.7	39.4	a	55.3	50.0	60.0

[a] Too few observations in this cell evaluation.
* Differences between the distributions are significant at 0.05 or higher levels of confidence.
+ Distributions have been truncated, with only the cells for increased inequality being reported.

Table 6
Relationship between Authors' Conclusions on Changes in Inequalities in Farmer-level Income during the Green Revolution and the Geographic Extension of the Study Area, Research Review 1970-1989 (n = 307)
(percentages)

	*Extension of the Study Area**		
Authors' Conclusions on Income Inequality	*Micro*	*Country*	*Macro*
Increased	28.7	42.9	60.0
Decreased	6.6	2.9	0.0
Unchanged	16.4	4.3	0.0
Not evaluated	48.3	50.0	40.0
n	(122)	(140)	(45)

Percentage of authors who found increased inequality when controlling successively for:

Control 1: Regional Identification of Author

	Micro		*Country*		*Macro*	
Conclusions on Income Inequality‡	*Asian*	*Non-Asian**	*Asian*	*Non-Asian**	*Asian*	*Non-Asian**
Increased	25.6	35.0	32.2	62.0	25.0	67.6

Control 2: Methodological Characterization

	Micro			*Country*			*Macro*		
Conclusions on Income Inequality‡	*Case*	*Analytical*	*Essay**	*Case*	*Analytical*	*Essay**	*Case*	*Analytical*	*Essay**
Increased	33.9	18.6	34.8	a	29.3	50.0	a	83.3	57.9

Control 3: Geographic Location of Study Area

	Micro		*Country*		*Macro*	
Conclusions on Income Inequality‡	*India/ Philippines*	*All Other**	*India/ Philippines*	*All Other**	*India/ Philippines*	*All Other**
Increased	16.7	55.4	39.4	50.0	a	60.0

[a] Too few observations in this cell evaluation.
* Differences between the distributions are significant at 0.05 or higher levels of confidence.
‡ Distributions have been truncated, with only the cells for increased inequality being reported.

Studies in which different research orientations were used also had very different conclusions (Table 4) —in case studies (community and farm) less than one-third showed that disparities increased and almost 37 percent concluded that farmers' income distributions were either unchanged or becoming more equal. In the analytical studies (including theoretical ones), a low proportion (28 percent) concluded that income disparities were increasing; the interpretive essay, by contrast, had the highest proportion of conclusions that farmer income disparities had increased (50 percent) and only 4 percent showed no change or greater equality.

As shown in Table 5, fewer of the studies carried out in India and the Philippines concluded that income distributions became more unequal during the Green Revolution period (29 percent) compared to studies located in other parts of the world (55 percent). Comparably, there were differences in the distributions of conclusions in studies of differing geographic extensions of areas (Table 6). Micro-level studies had the lowest fraction of conclusions that farmers' income disparities had increased (29 percent); country-level studies showed intermediate proportions (43 percent); and, macro-regional evaluations had the highest proportion (60 percent) of conclusions that income disparities had increased.

In each of these zero-order comparisons the hypothesis that there were differences in the distributions of authors' conclusions on the issue of income disparities among farmers when the studies were classified by the various characteristics held at a very high probability that the relationship existed when tested against the chi-square distribution, greater than the 0.001 level of confidence. The strengths of the relationships were much less pronounced. Using "phi" as an approximation for the strength of the relationship, the values ranged from 0.27 to 0.44.

A major concern of this exploration has been to attempt to disentangle the disparate interpretations of the effects of the rapid introduction of high-yield varieties technology on the distribution of benefits among producers and to understand better what cumulative research results can tell us about the process. Notwithstanding that the overwhelming majority of authors concluded that inequalities increased in the distribution of benefits among producers, agency officials and some academic analysts asserted that the technology does not exacerbate inequality and may even result in more equitable distributions. When the full body of research was systematically sorted relating authors' conclusions on income disparities with these four structural or methodological variables, the contingency relationships showed that the distributions of research results were different for each of the independent variables. These classifications of the hypothesized relationships were associated with different distributions of conclusions. The author's regional origin, the methodological approach, the location of the study regions, and the geographic extension of the area studied seemed to influence the results of a piece of research and begin to explain the disparities among both researchers and the users of research about what the overall research effort shows.

Each zero-order relationship was further tested by controlling for the effects of the other three. The differences in proportions of authors who found increasing inequality with the control variables are given in the lower panels of Tables 3-6. In

almost all instances the basic relationships held, that is, there were differences in the distributions of authors' conclusions associated with basic structural and methodological characteristics even when controlling for the other factors. The total number of observations in the study constrained the analysis to one control variable at a time. Even with one control variable, however, it was possible to discern the shift in the distribution of authors' conclusions on the question of changes in farmer-level income inequality during the Green Revolution period as a function of structural or methodological variables, both individually and in interaction with the others. To illustrate: although about 40 percent of the studies here reviewed concluded that farmers' income disparities had increased (Table 1), for studies based on community or local farming-region case approaches and those located in India or the Philippines (the two most favored locations for the new technology), the proportion of conclusions showing negative spread effects declined to only 20 percent (control 2 in Table 4). By contrast, for studies that used the expository essay and for which the study was located in any other part of the world, or which was not a specific area, the proportion that concluded that farmers' income disparities increased was over 58 percent (also, control 2, Table 4). Depending on which part of the overall research record is reviewed, results can be drastically different. As can be noted, similar results were obtained in the other contingency tables.

Thus research on the consequences of the rapid introduction of improved varieties technology in Third-World agriculture may be conditioned by the structural and methodological circumstances under which it was undertaken. If an author is preconditioned to expect favorable spread effects from the technology; if the area is selected in the most favorable zone ecologically, locationally, and in terms of social environment, and if the methodology concentrates on local circumstances, negative effects are less likely to be noted. Lipton and Longhurst (1989) observed that an excessive number of studies have been carried out in a limited number of more favored regions. By contrast, more generalized interpretive essays, which look at factors such as social and political power, class and caste prohibitions, and institutional structures, all of which may constrain the spread effects of powerful new technologies, exaggerate the negative distributional effects and overlook important positive elements at work in local areas and in specific circumstances.

It is also possible that in this case of the Green Revolution, an overarching element not analyzed here is at play. Some participants, both those in the administration of programs and in the study of this technological intervention, perceive it as a relatively isolated phenomenon with its own set of influences, opportunities, and limitations and tend to find substantially positive consequences. The technology has been identified as a biological improvement with few or no inherent economies of scale. The improved seeds, the fertilizer, the water control, and the chemical disease, insect, and weed control are all substantially divisible inputs; they work as well on minimally scaled operations as on larger ones. The technology is scale-neutral; no advantages are obtained between different sized farming units. An ancillary assertion is that all cultivators, large and small, are profit maximizers. Shown that opportunity affords, peasant or larger-scale farmers will respond rationally in the administration of available resources recognizing

that there may be differing responses to distinct risks or perceptions of risk (Schultz, 1964; Walker, 1989).

This mind-set, maintaining a clear distinction between the technology used and other institutionalized elements of an agricultural system, can be illustrated by reference to a carefully executed evaluation of the Green Revolution experience by M. Prahladachar (1983). Four elements of the social, political, and economic effects of the Green Revolution in India were explored: income distribution among producers; income effects on landless laborers; changes in factor shares resulting from the increased productivity of the improved varieties; and effects on regional income disparities. For each of the first three elements and using results from selected published studies, he concludes that the "pure" effects of the new technology facilitate positive spread effects. Regarding income distribution among cultivators within some areas Prahladachar concludes that the regressive impact "which is indeed real and serious, is not caused/accentuated by the new technology as such, but by the non-neutrality of their economic, social and political institutions" (p. 940).

He goes on to state that the employment effect of the new technology "in India does reveal a positive influence, although there may be differences about the quantum of additional employment generated and the adequacy or otherwise of the increase in wage rates to keep pace with the increases in cost of living, etc." (p. 940).

With respect to factor shares, Prahladachar observes that although the absolute status of the landless laborer improves,

> the owners of land and capital have gained relatively more than the laborers in the increased production due to MVs [modern varieties] (The latter result with MVs, which emerges essentially due to interaction between 'augmentation effects' of new technology —requiring less of every input per unit of output— and peculiar supply elasticities of factors of production —land, labour and capital— is often misconstrued to mean that there is a labour-saving bias in new technology.) (p. 940).

Even with respect to the fourth factor, interregional disparities, the author cites results from empirical studies showing a widening effect and suggests that

> in the coming years (i) if the differentials in development of physical and institutional infrastructures among the regions are narrowed, (ii) if the new technology of MVs is made available to a wide range of crops, and also more and more environment-specific varieties are evolved, (iii) if adequate attention to the problems and prospects of small farm management is given, and (iv) if the gains from new technology in the favored regions are shared by other regions (through appropriate government action), it is possible to visualize an altogether different scenario! (pp. 940-941).

This careful and balanced review for the case of India draws a clear distinction in viewing the modern varieties program as an agronomic intervention separate from the institutional conditions that circumscribe an agricultural system.

The contrasting overview perceives technology and its improvement as but one facet of an integrated agricultural system. The whole system is perceived as affecting the results of changes in any one aspect. Established production practices exist in balance with the historical realities; adjustments based on empirically derived marginal and accumulated improvements have occurred; changes in past periods have been few because the traditional practices were in balance with the full set of controlling institutions in the countryside. The Green Revolution did not arise within this oft-times static environment but was superimposed from outside in response to shifts in the political, social, or economic environment. The Rockefeller Foundation serving as the transfer agent for the new agronomy of the United States to Mexican agriculture during the Second World War and its aftermath is an early example (Jennings, 1988; Perkins, 1990). The Green Revolution was initiated with the introduction of the Mexican improved wheats to the subcontinent in the near-famine threats in the mid-1960s (Dalrymple, 1969).

This alternative view on the introduction of technological change in agriculture as a guiding orientation is that technology is only one part of an integrated agricultural structure. The limits of caste and class, landholding institutions, political power structure and social relations, farmers' differential access to information and credit, rural labor relations, location and market conditions, and government farm price supports and input subsidies all interact to influence, and in many respects control, the use and effectiveness of new technology and the distribution among producers of the benefits from it. Within this perception, the negative influence on equitable distributions of benefits is not an aberration from "good" policy decisions but part of the integrated social, political, and economic structure.

The major study on the Green Revolution carried out some years ago by the United Nations Research Institute for Social Development (UNRISD) was guided by this concept of technology embedded within a broad agricultural system. Andrew Pearse (1980) summarized and interpreted the many component elements of the UNRISD undertaking. His review concludes that the technological strategy for development is inexorably integrated into and becomes part of the social relations in which it is inserted. It is not possible to disassociate the social and economic effects of the technology from the social system in which it is functioning. The structure of the social system determines both that the technological package will be implemented and how the benefits will be distributed. It is not possible to isolate one from the other. As Pearse put it:

> What emerges [...] is inevitably a critique of Green Revolution strategy and not a rejection of the technology itself, the application of which can be widely beneficial under appropriate conditions [...] When inequalities exist already, the Green Revolution's strategy results in the persistence and generation of poverty for the majority of people in rural areas (pp. 170 y 207).

In addition to the several structural and methodological factors that have been

demonstrated here as influencing the results researchers have found in their work, the differences in perception of technological intervention may influence the results. Although not directly tested in this statistical interpretation of the literature, how technology is perceived may be of importance in appreciating why there are such strongly held contrasting views of the effects of the HYVs technology on Third World farmers. If the new technology is considered to be a relatively simple, albeit extremely important agronomic change, it may be hard to see that, as a single intervention, it has anything but positive benefits. To the degree that tenants are displaced, that labor-substituting capital is introduced, that public credit, input, and market benefits are oriented to selected subgroups of farmers, increasing disparities can be seen as caused not by the technology used but by a failure in policy formulation and implementation. The contrasting overview is that technology is but a small part of an integrated agricultural production system. The technology may be scale-neutral, but the ancillary controlling elements within the production system are not. The full set of forces at work within the production system interact, with the perceived consequence being that the increased productivity leads to continuing and even increased inequities within the production sector. Both implicitly and explicitly the argument is that before, or at least contemporarily with, the introduction of the productivity-raising technology, adjustments must be made in the associated structures of the production system if broad spread effects and alleviation of poverty among producers are to result from the technical change.

4. Conclusions

Over 80 percent of the sample of published studies reviewed here with conclusions on the effects of introducing the higher-yield varieties technology on producer-level and interregional distribution of benefits concluded that greater inequality resulted. Notwithstanding this preponderance of evidence, the overwhelming conviction of operating agencies, both local and international, has been that the improved technologies offer the best solution to the problems of agricultural and rural development and growth. Indeed, a significant number of scholars join in this very positive view of the impact the new technology has on agricultural and rural regions. The argument is that the nature of the biologically-derived improvements assures growth in agricultural productivity, greater employment per unit of area cultivated, and higher incomes both for the poorer and the better-situated cultivators and farm workers. If some distributional problems are identified, they may be explained as errors in measurement of the effects (early studies based on inadequate information as contrasted to more completely documented later studies), as minor inconveniences compared to the production imperative of adequate food supplies for rapidly expanding populations, as a consequence of inadequate institutional arrangements, or as a result of mistaken public policies toward agriculture and rural development.

In contrast to this predominant view of action agencies and a number of analysts (both those associated with these agencies and some academics) there are students of

the Green Revolution who see less desirable consequences, particularly for producer-level distributional effects, and a weakness in the strategy for poverty alleviation. This latter group tend to see technology as but one component of a broad set of institutionalized factors which control and determine the distribution of benefits to producers from the increased productivity. A strategy based primarily on technology may have negative effects when the other institutional structures of the overall system are ignored.

This study has explored factors that may explain some of the differences in appreciation of what the accumulated research record informs us on the issues of producer-level distributions of benefits and interregional advantages and disadvantages of the HYVs strategy for agricultural and rural development. Because almost all studies indicated negative interregional effects, and few supporters of the strategy suggest that interregional effects can be positive until new generations of technology can be developed for the ecologically disadvantaged regions, attention has concentrated on the issue of farmer-level income distribution. The analysis raised serious doubts about the proposition that later studies came to different conclusions than had the earlier ones —there was no statistically significant difference in the distributions of authors' conclusions among early, intermediate, and later studies of the income-distribution effects of the introduction of Green Revolution technology in Third World agriculture.

With the issue of intertemporal differences in study results rejected as an adequate explanation, it was possible to look at several other structural and methodological factors that might explain some of the differences. Four factors were found to be associated with differences in the distributions of authors' conclusions on the spread effects of the new strategy: author's national origin, methodological approach, location of the study, and geographic extension of the study area. Further, when the above relationships were controlled for each of the other factors not only did the general relationships tend to hold, but there was sufficient interaction between the variables to give even greater distinctions among the resulting distributions. Combinations of studies categorized by these broad characterizations and then again by the control variables permit evidence quite distinct from the general run of results. An imperative in interpreting the message from cumulative research results is to be sure that the full body of research is included, and not just some category. This is generally true for all research areas and is an active area of research inquiry today —it is particularly important to the social sciences, where the paradigms are not universally accepted and the methodologies are disparate.

The consequences of the Green Revolution have been strongly contested; just what the effects have been and continue to be is important. A technological strategy for agricultural and rural development is politically attractive. If seeds, fertilizer, water control, and pesticides can assure a productive agriculture and a prosperous countryside, the struggles and dislocations of altering social relationships, landholding patterns, political power sharing, and other deeply entrenched arrangements can be avoided. If they cannot, however, other approaches are necessary to help alleviate the destabilizing and demoralizing effects of worldwide rural poverty. The assumption of applied research undertakings is that the results of research provide insight and direction for

action to move toward desired goals. Although no one study may be decisive, the expectation is that the wider body of results provides a basis for policy; only a systematic accumulation of the results of all relevant studies can give reliable guidelines for action.

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