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Agricultural Science, Invention and Productivity: An Analysis of the U.S. and Israeli Agricultural Research Systems

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Abstract. BARD Project US-876-84

Agricultural Science, Invention and Productivity: An Analysis of U.S. and Israeli Agricultural Research System.

The major objective of this project was to study the R&D activities of agro-industry firms in the Israeli economy. A secondary objective was to study the international aspects of these R&D activities including comparisons with U.S. agro-industry firms. The major objective was pursued through the conduct of a survey in 1986 of agro-industry firms and of inventors in Israel. The secondary objective was pursued through an analysis of invention data for Israel, 21 other developed countries and 20 other developing countries for the 1980-88 period.

The survey data from the survey of Israeli firms showed that over half of the firms doing R&D in 1986 had begun after 1975. About half of the firms report that they began R&D activity jointly with the establishment of the firm indicating significant economic activity based on expected gains from a new product or process. At least a third of the firms reported that the initial technological development on which they were working originated outside the firm, and in half of these cases this was in the public sector research institutions.

Approximately half of the agro-industrial patents were awarded to independent inventors many of whom subsequently were employed by or obtained ownership in a firm. Inventors were highly educated. Eighty-five percent had graduate degrees. Many had obtained patents abroad. The international study confirmed the fact that Israeli inventors are not only producing important inventions in Israel but that they are obtaining large numbers of agro-industrial patents in other countries.

Description of Cooperation

The Interdisciplinary Center for Technological Analysis and Forecasting at Tel Aviv University was the chief cooperating institution on the main project. Dr. Gideon Fishelson and Mr. Iran Bijouei were the key individuals.

The Economic Growth Center at Yale University provided access to its international patent data base for the supplementary project. Mr. J.D. Putnam and Ms. M. Ann Judd provided assistance.

Staff at the Hebrew University, Jerusalem and at Rehovot, at Tel Aviv University, at Yale University, at the Volcani Institute and at BARD headquarters all contributed to the project.

Benefit to Agriculture

The organization and conduct of agricultural research in public sector institutions has been important to agriculture in both the U.S. and Israel for many years. Studies of returns to this investment have documented their contributions. This study has shown that the private sector has also contributed to agriculture. It will enrich further analysis of economic growth in the agriculture sector.

As private agro-industrial firms expand their research, the public sector will be required to respond by changing its programming to complement private research to the extent feasible. This study will initiate the process of developing more effective complementarity between public institutions and private firms.

Final Report: BARD Project US-876-84

"Agricultural Science, Invention, and Productivity: An
Analysis of the U.S. and Israeli Agricultural
Research Systems"

Principal Investigators;

Robert Evenson, Zvi Eckstein, and Ariel Pakes

The purpose of the project was to study the origins, and the success/failure characteristics, of research activity in agroindustry in the Israel economy. Our first task was to decide on a procedure for obtaining the data that would enable us to analyze these issues.

We decided on a two pronged data generation procedure. One part of our efforts went to obtaining information on firms engaged in various aspects of agroindustry in 1986 (not all of whom engaged in R&D). We were afraid that limiting ourselves to a data set obtained in this way, that is from information from firms, would limit the relevance of our analysis in two ways. First research projects that were set up in firms that did not survive would not be sampled. Thus if the probability of the firm surviving was related to the probability of the research project being successful, by limiting ourselves to research projects that were undertaken by firms that existed in 1986, we would be selecting a sample of relatively successful research projects. This would limit our ability to make inferences on the degree of success, and the determinants of that degree, among the population of projects ever started. Our second reason for concern about limiting ourselves to information from firms was that we would not obtain enough information about the role of 'independent' inventors, and research institutes, in generating ideas that were eventually taken over by firms and worked into marketable goods and services.

These concerns lead us to gather a separate data set on all

patents taken out by Israeli inventors in Israel on products related to agroindustry. Past research indicates that patents are taken out at a relatively early stage in the research process (for discussion, see Pakes, 1986), so that by analyzing patents we were likely to obtain some information on projects that were never commercialized, and were not successful. Also, traditional folklore has it that patents are a much more important source of protection for products developed by small firms and independent inventors (see the discussion in Scherer, 1980).

The rest of the report is divided into three separate parts. The first consists of a subreport entitled; "The R&D Process in Research Centers and Industry Related to Agriculture in Israel", published by the Interdisciplinary Center for Technological Analysis and Forecasting at Tel-Aviv University. The subreport provides; the methodology for obtaining the data, the dimensions of the data that was obtained, and a tabular presentation of the relationships among some of the major variables of interest. We worked jointly with the Center for Technological Analysis to develop the methodology and questionnaires, and then sublet the actual data gathering to them (with periodic consultations whenever something did not go according to plans). We were satisfied that, given the difficulties of the problems involved in obtaining this data, they did an excellent job.

The second part of the report analyzes the data obtained from the firm survey and was written by Zvi Eckstein and Ariel Pakes. It, in turn, consists of four parts; a summary of some of the major

findings, a section on the origins of R&D activity, a section on the extent of investment in the R&D projects, and a section on the success of the R&D projects. The third part of the report is a paper entitled; "Israel's Agricultural Invention: An International Analysis", written by Robert Evenson and Johnathan Putnam. Unfortunately, we were not as successful as we hoped to be in obtaining information on the inventors which registered the patents in our samples. As a result, Professor Evenson expanded the analysis and went to international patent data sets to gather additional information on the extent to which Israeli patentees patented abroad, and foreign patentees patented in Israel (all in agroindustrial products), as well as to compare the characteristics of Israeli patenting in these fields to patenting in other countries. That paper also has four parts; the first is a comparison of legal systems designed to stimulate innovations in these fields, the second is an analysis of Israeli patenting both over time and by different fields of agricultural technology, the third compares the Israeli developments to developments in other countries, and the fourth summarizes the information gathered in our own data generation process, and compares it to the information available from the international data sources.

We hope this report is of use to researchers and policy makers active in related fields as well as to academics. If we can be of any further assistance to individuals interested in these topics please do not hesitate to contact us.

Report on the Firm Survey

by

Zvi Eckstein and Ariel Pakes

This part of the report is divided into four sections. The first section outlines the procedure used for obtaining the firm level data (referring the reader to the ICTAF report for details). The second section analyzes the data on the origins of R&D activity. The third section analyzes the data on the amount of investment in R&D and the time it took for the completion of the R&D projects, and the fourth section attempts to unravel the information available on the success of the R&D projects analyzed. We conclude this introduction with a brief summary of the conclusions reached in each of the last three sections.

Much of the current R&D activity in Israeli agroindustry began only recently; over half of the firms doing R&D in 1986 (and for whom we had the relevant information) began their R&D activities since 1975. In addition, among the firms for whom we have the required information, we find that about half of them report beginning R&D activity at about the same time as, or even before, the firm was in operation. We presume that this is likely to indicate a situation in which the firm was founded in order to exploit a research opportunity. As one might expect, the firms founded in this manner were characteristically quite small, about a quarter of the size of firms that had been in operation before they began their R&D activities.

A large part of our study focused on the location of, and the sources of both the knowledge and the experience that lead to, the initial developments which resulted in the R&D activity. We divided up the data among four groups of firms; one for whom the initial developments occurred in the firm that did the subsequent R&D, one for whom the initial developments occurred outside the firm that did the subsequent R&D and we know the institutional framework in which that development occurred, one for whom the initial development occurred outside the firm that did the subsequent R&D but for whom we do not know the institutional framework on which that development occurred and a group for which we do not know whether the initial development was inside or outside the firm that did the subsequent R&D. The results were as follows. In only 17% of the cases do we know the initial development occurred inside the firm. We do not have sufficient information to judge in about a third of the cases. In fully a third of the cases the initial development that lead to the R&D occurred in a known institutional framework that was not the firm that did the subsequent R&D, and in another 17% of the cases it occurred in an unknown institutional framework outside of the firm that did the subsequent R&D. This last group consists of firms which report starting R&D before or at the same time as the firm was founded, but do not report the framework that generated the idea leading to the R&D. The patent survey indicated that about a half of the (176) patents taken out in agroindustrial fields after 1975 were registered by independent inventors (in contrast to research institutes or firms), and we

expect that the last group of firms consists primarily of the firms set up by these independent inventors.

Thus for about 50% of the R&D performers in our data we know that the initial development that lead to R&D occurred in a location other than the firm that did the subsequent R&D. Moreover, about a half (of the fifth) of the cases for which we know that the initial development occurred at the firm that did the subsequent R&D, report that the basic experience or knowledge that lead to the initial development was acquired at a different institution (this also occurs for about a quarter of the third of the firms for whom we do not have the information required to classify the location of the initial development).

These figures raise several issues. First the accounting frameworks we use for analyzing the causes of productivity increases may be misleading. Traditionally, those increases would be attributed to the R&D done in the firm that did the subsequent R&D, even though they are partly a result of the resources expended in another location. Indeed, this may be one of the reasons why firm level production function estimates have often implied supranormal returns to investments in R&D at the same time as we observe declining or flat R&D investment (for a discussion, see Pakes and Schankerman, 1984). One only invests when one perceives that there is a profitable idea to be developed, and if those ideas are not generated by the outcomes of the firm's own R&D, then there is no necessary relationship between those outcomes, and subsequent R&D investments.

More fundamentally, the institutions generating the initial developments and the basic knowledge that underlies them, together with the mechanisms by which those developments are transferred to the firms which use them, are determinants of the nature of the growth in the productive capacity of the economy, and of the appropriate role for (and of the effectiveness of) public policy in facilitating such growth.

In about two thirds of the cases in which the initial developments occurred outside of the firm that did the subsequent R&D, at least one of the individuals responsible for that development, or at least one of the 'inventors', became either an employee or an owner of the firm that did the R&D. Mobility of personnel then, particularly of scientific personnel, seems to be an important mechanism for facilitating information flows from one institution in the economy to another. As for institutional affiliation, the one third of the cases in which the initial development did not occur at the firm that did the subsequent R&D and for which we do know the institution at which the initial development took place, are about equally divided among cases where the initial development occurred at a research institute, and cases where the initial development occurred at another manufacturing firm. The cases reporting that the basic knowledge underlying the development occurred outside of the firm are also about equally split between cases where that knowledge was generated at research institute, and cases where it was generated at another manufacturing firm. Interestingly, in almost all of the cases

where the initial development occurred at a research institute one of the individuals associated with the initial development became either an owner or employed by the firm that did the subsequent R&D, whereas this occurred for only about half the cases in which the initial development occurred at another manufacturing firm. Section 2 of this report discusses these (and related) findings in more detail, and considers some of their possible implications.

The inventors were, on the whole, very well educated. About half of the group for which we had the relevant information (and this included 85% of the sample) had graduate degrees, and most of the rest had engineering degrees. A similar result was obtained from the survey of patentees, and this leads us to wonder if the quasi-monopoly power generated by developing and marketing the output of a new idea is not a major component of the returns to graduate education in related fields. It was also interesting to note that in about 15% of the cases for which we had information the initial R&D was not actually done at the firm (and there was no obvious relationship between the location of the initial development and the cases in which the R&D was done outside the firm). In almost all of the cases in which the R&D was not done at the firm it was done at a research institute. There is some indication that research institutes centralize scarce resources which are only needed sporadically by the firms (and which, presumably, have high sunk costs associated with use).

We were not able to obtain accurate information on the profitability of the firm's initial R&D project. We were, however,

able to obtain answers to questions on whether the project resulted in a new product or process, or a new patent. It is important to keep in mind that these are dichotomous variables that might indicate whether there was some minimal threshold of success, but do not indicate the extent of that success. Over three quarters of the projects generated a new product or process, and about a third generated a new patent. Since we only sample among projects which are in firms which survived until 1986, we have to be careful in interpreting these figures. Projects that were in firms that liquidated before 1986 are more likely to have been projects that failed, so the percentage of projects ever started that passed our minimal success threshold is likely to be smaller. As another example of biases generated from our sample selection criteria we note that fully 86% of the firms founded at the same time the R&D project began developed a new product as a result of the project, while this percentage for the firms that were already in existence prior to beginning of R&D was only 66%. Part of the difference between these two figures is a result of the fact that unsuccessful endeavors in newly founded firms are more likely to result in liquidation of the firm than unsuccessful endeavors in firms that had been in existence for some time previous to the start of R&D.

Most of our potential explanatory variables did not have significant explanatory power in accounting for the success probability. An exception was the education of the 'inventor'. Projects started by individuals with graduate degrees tended to have a lower success probability. These were projects which were

also, on the average, more costly and which took more time to complete. A likely explanation of these findings is that projects generated by inventors with graduate degrees tend to be more complex, and hence both less likely to produce a marketable good or service, and more costly. On the other hand we would expect such projects to produce more profits if successful, a hypothesis we were unable to test with our data.

On average firms in our sample invested about a quarter of a million dollars in their first R&D project, took about 26 months to complete it, and used about five man years of labor in the process. Other than education of the inventor, the variables which tended to have a significant impact on the quantity of resources invested in the project are; whether the project took place in an existing firm or in a firm which was founded at about the same time the project began (the latter projects being, on average, smaller), the size of the firm at the time the project began (larger firms tended to have larger projects), and an indicator for whether the inventor was outside of the firm when the initial development on the project occurred (also a positive effect).

One clear result from the analysis of the investment variables was that there was a large positive correlation between the size of the investment in, and the time to completion of, the projects. This is contrary to the traditional analysis of the relationship between the time to, and the cost of, development of R&D projects wherein a negatively sloped feasibility frontier connects the two variables. Of course the traditional models assume a set of

homogeneous projects, and it could well be optimal to both invest more in, and take longer to complete, more difficult projects (presumably the more difficult projects are more profitable if successful). Of course, once we allow for uncertainty we might well expect to find a positive correlation between time to completion and investment in a project even among a set of homogeneous projects. In a model that allowed for uncertainty and sequential decision making, projects which had later stopping times will be those that did not unravel immediately and hence required further investment. Following an analogous lines of reasoning, we could generate negative relationships between both investment, and time to completion, and the probability of success of a project (and in fact the observed relationship between success and time to completion have ambiguous signs). The underlying point to be made here is that investment, time to completion, and success, are jointly endogenous variables, and we need a more detailed model (and probably a longer, larger, and more detailed data set) to unravel the structural relationships among them.

The next section of this report provides an overview of our firm survey and a guide to the more detailed accompanying ICTAF report on that survey. Section 2 provides our analysis of the origins of the R&d activities, while sections 3 and 4 provides our analysis of the investment variables, and the probabilities of success, repectively.

1. The Firm Survey

We defined the population of firms from which to sample to include all producers of 'agriculturally related' goods. This included producers of inputs that are used in agricultural production (pipes, fertilizers, irrigation system,...) and producers of processed agricultural products (foodstuffs, etc.). We found that the population so defined included 376 firms in 1986, and these firms are listed on pages 60 to 71 in the ICTAF report. Table 1 below provides a cross-classification of this population by major field of activity and region. One third of the firms are located in the Tel Aviv area, and one-half are in the northern part of the country. The major activity of 35% of these firms is the production of foodstuffs, about a fifth of them produce plastic products, and another fifth produce various forms of chemicals and fertilizers.

Our original questionnaire was sent to all firms in this population. The response rate from the questionnaire was very low (about 20%); too low to consider using the questionnaire as a source of data. We then used various other sources of information to construct a sublist of 115 firms from the original population which did R&D. To the best of our knowledge the sublist is complete; that is, it includes all those firms from the original population that were engaged in R&D activities. We proceeded to interview one hundred of the firms on the sublist. It is the responses from these interviews that we analyze in the next three

Table 1
Industrial Firms with Activity Linked to Agriculture In Israel by Main
Industries Sectors and Regions
(Numbers of Firms)

Section/Region	Jerusalem Rehovot	Tel Aviv Hertzlia	North	South	TOTAL
Vegetable fruit processing	10	24	27	5	66
Wheat, Chicken, Fish processing	1	5	20	1	27
Foodstuff/others	2	17	14	2	35
Diagnostic Pharmaceutical Biological Chemicals	11	2	5	-	
Fertilizers Pesticides	-	7	5	2	
Other Chemicals	2	10	19	2	
Metal Products Machinery	6	8	19	-	33
Irrigation Products	4	8	23	1	
Plastics, others	2	20	40	9	79
Electronics	3	3	3	-	
Others	1	12	8	5	26
TOTAL	42	124	183	27	276

sections. Thus we believe our sample to include over 85% of the firms in agroindustry that were actively engaged in R&D in 1986.

Table 2 provides the firms in the original population, the firms in the sublist that do R&D, and the firms we sampled, by field of activity. If we compare the sample to the sublist doing R&D we find that we undersample plastics somewhat, and oversample electronics -- but both deviations are very minor. The criteria of including only firms that do R&D had much more bite. It eliminates the vast majority of the firms in both foodstuffs and in plastics, as well as about two thirds of the firms in metal products and other chemicals - but it keeps essentially all the firms in fertilizers, pharmaceutical and biological chemicals, irrigation products, and electronics. Thus though these last four fields contain less than a quarter of the population of firms, they include well over half of the subset doing R&D, reflecting the apparent fact that almost all surviving firms in these fields do R&D.

The actual questionnaire answered by the firms is provided on pages 78 to 83 of the enclosed ICTAF report. The data is available on the attached diskette as a LOTUS worksheet. Part 1 of the questionnaire asks questions on the name, telephone number, address, year founded, and annual turnover of the firm. Part 2 asks background questions about the R&D activity of the firm (the location of the R&D, whether it has been continuous over time, and the fields of R&D was directed at). We also asked questions about ownership patterns and the financing of investments (both before

Table 2

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The Firm Population Activities Linked to Agriculture and Our Samples
(Number of firms)

	Total Number of Firms	Firms with R&D	Sample Firm with with R&D Activity
Foodstuff/others	128	16	12
Diagnostic Pharmaceutical Biological Chemicals	18	16	13
Fertilizers Pesticides	14	12	10
Other Chemicals	33	8	10
Metal Products Machinery	33	10	13
Irrigation Products	36	28	21
Plastics	79	14	11
Electronics	9	10	10
Others	26	1	0
TOTAL	376	115	100

R&D began, and currently). Part 3 of the questionnaire focuses in on the original inventor(s), or those individuals responsible for the ideas underlying the first major research endeavour of the firm. We asked about; the workplace of the inventor at the time of the first development on the idea that eventually lead to the R&D activity, the source of the inventor's basic knowledge or experience that lead to this development, the physical location of the R&D at the beginning of the R&D programme, the extent of investment in the project (in both monetary, and man year, terms), and the time it took to complete the project. Part 4 of the questionnaire asks about the success, or profitability, of the R&D projects of the firm, and the last part of the questionnaire tries to provide information on the labor force of the firm; (their educational background, and the extent to which they are involved in R&D). The response rate varied among questions, and the analysis done in the next three sections tries to focus in on the questions for which the response rate is high.

2. 'Start-up', or the Origins of R&D Activity

Table 3 summarizes the available data on the dates at which R&D activity was initiated in the firms in our sample, and on the dates at which the firms themselves were founded. We have information on the date at which R&D activity began for 63% of our sample. Of these, 54% did so after 1975, and 65% began R&D after 1970. It seems that privately funded R&D activity is a relatively

Table 3

Year of Founding of the Firm, and of Startup of R&D Activity

		<u>Not Known: Fraction Among Firms For Which Year is Known</u>							
		:	pre	1955	1961	1966	1971	1976	1981
		:	1955	-60	-65	-70	-75	-80	-85
Year Firm		:							
Founded	10	:	.19	.08	.17	.12	.16	.20	.09
Year R&D		:							
Started	37	:	00	.05	.10	.21	.11	.27	.27

recent phenomena in Israeli agroindustry, or, more precisely, that most of the firms currently doing R&D began this activity only recently. There is information on the founding dates of the firms for 90% of our sample. Of these, 29% of the firms were founded after 1975, and 45% were founded after 1970. Recall that the survey was done in 1986, so this implies that almost a third of the firms doing R&D in 1986 were less than 10 years old. The firms themselves then were also relatively recent startups, though not, on the whole, as recent as the R&D activities within them. The fact that not much time elapsed since the founding of the firms (and/or their R&D labs) simplified the task of obtaining information on the origins of the firms and their R&D activities.

Table 4 provides the distribution of the difference between the time R&D began, and the time the firm was founded - a variable we label TD. We have information on TD for 61% of our sample. The striking finding from this table is that 27 (or almost half) of them actually started their R&D activities either at the same time, or before, the time the firm was founded (and another 9, or 15%, began R&D within 3 years of the firm's beginnings). This suggests that many of the firms were founded in order to exploit a research opportunity.

One factor motivating our survey was a desire for a better understanding of the sources of the ideas that lead to the startup of R&D activity, and, hence, to the new products and processes that our subsequent analysis will show were generated by this R&D activity (apparently, for many of the firms in our sample, it was

Table 4

Time Difference Between Starting R&D and Founding of the Firm

<u>Not Known</u>	<u>: Fraction Among Firms For Which Difference Known</u>								
	: <0	0	1	2	3	4	5	6-25	25+
39	:.10	.34	.03	.03	.08	.05	.03	.20	.13

the same ideas that lead to the establishment of the firm itself). There are at least two reasons for being interested in the sources of these ideas. First, they have both a private and a social value, and, given the often hashed out problems in establishing markets for 'knowledge', the social and private values need not be equal. Whether or not they are depends on the precise nature of the institutional arrangements prevalent in the situations which generated the ideas. A second (though related) reason for our interest is that these ideas are sources of productivity increases, and in order to know how to incorporate them into traditional accounting frameworks we need to know more about the situations which generate them.

There were at least two questions in the survey that were related to the sources of the ideas which lead to R&D activity. We asked about the workplace of the individual(s) responsible for the 'first development' at the time that development was made, and we asked about the source of the basic knowledge or experience that lead to that development. Table 5 provides one way of summarizing some of the information provided by the answers to these questions.

We do a primary cut on the reply to the question on the workplace of the individual responsible for the first development. Among those who list the firm doing the subsequent R&D as the place for the first development, we distinguish between three groups. A group which report R&D activity preceding, or starting in the same year as, the year the firm was founded. We assume that for these firms the idea leading to the first development was developed

in some other framework (as noted earlier our patent survey indicated about half of the patents in related fields were registered by independent inventors, in contrast to firms or research institutes, and we expect some of the firms in this latter group to have resulted from these independent inventors' attempts to develop and market their products). A second group consisted of firms that were in operation before the R&D activity began. For this group, it seems likely that the idea leading to the first development was generated in the firm that was responsible for the R&D. The third group is a group of firms for whom we do not know the relationship between the date of beginning R&D activity, and the date of founding of the firm.

83 firms answer the question about the workplace of the individual responsible for the first development. 27, or about a third of them, list an institution other than the firm responsible for the subsequent R&D. Another 14 (or 17%) list the institution responsible for the first R&D as unknown, but which report that R&D activity preceded, or began at the same time as, the firm was founded. Only 17 of the firms (or 20%) record that the firm was founded before it began R&D activity, and that the initial development leading to the R&D activity occurred within the firm. For 25 of the firms that record initial developments occurring at the firm that did the subsequent R&D, we do not know the relationship between the date R&D began and the date the firm was founded. The striking fact about these statistics is that they indicate that at least half of the developments which eventually

lead to the startup of R&D activity occurred outside of the firm which actually did that R&D.

More detail on the relationship that developed between the individual(s) that did the initial development and the firm that did the subsequent R&D activity is given in the following panels of the table. In 19 of the 27 cases in which the individual that was responsible for the initial development was in a known institution outside of the firm that did the subsequent R&D, one of the individuals associated with that development was subsequently employed by the firm that did the R&D. When we disaggregate by the type of institution the individual was employed in when that individual made the development, the numbers differentiate between cases in which that institution was a research institute or a parent firm, and the cases in which that institution was another manufacturing firm. In only 5 of the 10 cases when the institution was another manufacturing firm, did the developer become employed by the firm that did the R&D, while this occurred in 14 of the 17 other cases. In this respect the figures for the firms in which the R&D occurred at or before the founding of the firm, but for which we do not know the institution which generated the ideas leading to the initial development, are similar to the figures for the cases in which the initial development was in a research institute (in 13 of the 14 of these cases one of the individuals responsible for the initial development was subsequently employed by the firm which did the R&D).

Recall that the figures indicate that in at least 50% of the

cases the initial development that lead to the R&D activity occurred outside of the firm that did the subsequent R&D. In 32 of the 41 cases for which this occurred, the firm which subsequently did the R&D employed one of the individuals responsible for the initial development. Indeed this occurred in 27 of the 31 cases which record the initial development outside of the firm, but do not record it as occurring in another manufacturing firm. It seems clear, then, that a major avenue through which new developments which occur in one location get embodied in research projects, and subsequent new marketable goods and services, in another, is the mobility of personnel. Scientific personnel move both; 1) between existing and from existing to new firms, and 2) from research laboratories to both existing and to new firms.

It has long been recognized that the mobility of personnel, particularly of scientific personnel, is a possible mechanism through which externalities are generated (for an early reference see Arrow, 1962). Perhaps the most cited case of the empirical prevalence of this 'spinoff' phenomena occurred during the development of the U.S. semiconductor industry (see Braun and MacDonald, 1978, and the 'family' tree of firms in Freeman, 1974). The structure of the incentives and rewards associated with this phenomena depends very much on the type of contracts between both; the institution doing the initial development and the individual 'spinning off', and the firm doing the subsequent R&D and this individual. Pakes and Nitzan (1984) provide an analysis of optimal

labor contracts for scientific personnel in firms which realize that the scientists working for them have the option of splitting off to join (or startup) a rival enterprise, and show that, at least in certain situations, contracts can be devised such that the original firm internalizes most (if not all) of the value of the information it provides to its subsequent competitors. Moreover, the optimal contracts will actually generate spinoffs for some realizations of the relevant random variables, and have features, such as stock options, which are frequently observed among the contracts for scientific personnel in 'high-tech' industries. The table also lists figures on the activities of the individuals after they moved, as this provides some indication of how further modelling of the spinoff phenomena should proceed. In 15 of the 32 cases in which the initial development was outside of the firm, one of the individuals become an owner of the firm, and in another 11 cases the individual did not become an owner but did work in the firm's research department.

Even in situations where there was mobility of personnel and the Pakes/Nitzan (1984) analysis is relevant, there remains the question of whether the individual that actually splits off from the initial firm earns the full social benefits of the idea which lead to the project (if the individual does not earn these benefits, the initial firm will not be able to write an acceptable contract which transfers those benefits to the firm). Further, accounting frameworks will not generally associate the increase in

productivity emanating from the activities of the original firm with the costs of those activities. Finally the theoretical analysis is not likely to be relevant when the initial development occurs in a research institute, and we do not know of any analysis of either; the relationship among the returns to the various agents, or of the overall return, in these cases. Among other problems, this complicates the analysis of the social returns to the (generally publicly funded) research that occurs in these institutes -- even though we seem to be clear on the fact that this research does lead to productivity gains (see the review by Evenson in Reynolds, 1975, and more recently, Jaffe, 1988).

In addition to the cases in which the initial development occurred outside the firm that did the subsequent R&D and there was mobility of personnel, there remains the 9 cases in which the initial development occurred outside of the subsequent R&D performer and none of the individuals involved in that development moved. If there is a market mechanism which allocates some of the private returns from the output eventually generated from these developments to the firm responsible for them, we do not know what it is. In addition, in 17 of the 73 (or between 1/4 and 1/5th of the) cases in which the initial development did not occur in another manufacturing firm, the source of the basic experience or knowledge that lead to the first development did. This included about a half of the cases for which we know that the first development occurred in the firm that did the subsequent R&D. We suspect that in most of these cases, as well as in the cases where

the initial development occurred at another manufacturing firm and there was no transfer of personnel to the firm doing the R&D, there were externalities, or nonmarketed spillovers, of the type discussed in Spence (1984) and Romer (1986), that went along with the transfer of information among firms (see Jaffe, 1986, for an attempt to quantify and estimate such externalities).

We found it interesting that research institutes seem to play almost as large a role in generating these externalities as other firms do -- at least in Israeli agroindustry. In addition to the 13 cases in which the initial development was recorded as occurring in a research institute, there were another 10 cases which reported that the other source of the basic knowledge or experience that lead to the initial development was a research institute. That is, research institutes were either the location of the initial developments, or the source of the basic knowledge or experience that lead to it in 23 of the 83 cases for which we have information. Other manufacturing firms were either the location of the initial developments or the source of the basic knowledge and experience that lead to it in 29 of the 83 cases. So research institutes seem to be almost as large a potential source of externalities as other manufacturing firms. This may be partially a result of a greater degree of 'closeness' between the sciences, on the one hand, and private research endeavors, on the other, in agroindustry, than in other parts of the economy that seems to come out of the sparse empirical work on these topics, (see Nelson, 1986).

The answers to at least two other questions on the beginnings of R&D activity are informative about the environments that lead to new R&D projects. First, for the most part, the inventors of the first developments were highly educated. Of the 85 responses we had to this question, 34 (or 40%) replied that the inventor held a graduate degree, 33 replied that the inventor had an engineering degree, 7 replied that the inventor had a bachelor's degree, and only 11 (or 13%) replied that the inventor had no degree from a university (of these one had a certificate from a technical institute). Graduate education was more likely to be found among inventors which were outside of the firm at the time the initial development was made (it was found in 41% of those cases), and was particularly likely when the inventor was at a research institute at the time the initial development was made (it was found in 61% of these cases). We were struck by the prevalence of graduate degrees (particularly of Ph.D's) among the inventors. Indeed, it seems that a significant source of the returns to graduate education both to the economy, and, depending on the institutional set up, possibly to the individual, may be that it gives individuals an increased ability to generate new production processes. Note that the productivity impacts of the effects of graduate education in generating production processes would not be picked up by traditional firm-level production function estimates of the effects of graduate education - though wage equations might pick up that part of the production-process generating effects that are privately appropriable.

Another question on the survey asked where the initial research of the firm (in contrast to the development that lead to this research) took place. About 80% of the 89 respondents answered that it took place in the plant, but there was a significant 16% that replied that it took place in a research institute. There was not a very tight relationship between the location of the inventor when the first development was made, or the source of the basic knowledge that lead to that development, and the framework in which the initial R&D took place. Of the 14 projects which had initial R&D done at a research institute, only 3 were from the group of 14 that had listed a research institute as the source of the knowledge that lead to the first development. Indeed the only reasonably strong finding on the projects which used a research institute as a location for their R&D was that almost 60% of them were generated from knowledge sources outside of the firm, while only 40% of the projects in which the research was done at the plant emanated from knowledge sources outside the plant. The data seems to indicate that ideas are generated from one set of institutions, and then reallocated for subsequent research to another according to a different set of criteria. In particular, the ideas generated from sources outside of the firm may be more likely to require resources with high sunk costs of employment and which the firm would not typically have need of. The research institutes may then hold resources which it would be too costly for any one firm to maintain at all periods of time, but which the firm may want to access as the need arises. All in all

a rather reasonable way to overcome economies of scale problems that may arise due to the periodic need for specialized resources in research.

Table 5. Origins of the Initial R&D Project

Question: What was the workplace of the individual(s) responsible for the first research development at the time that development was made.

Number answering the question	83
Of these (see text for determinants of subdivisions),	
A. The institution is known and it is not the firm that did the initial R&D	27 (33%)
B. The institution is unknown, but the R&D began before, or at the same time as, the firm was founded	14 (17%)
C. At the firm doing the initial R&D	17 (20%)
D. Unknown	25 (30%)

Details on group A. above.

"Institution known and it is not the firm that did the initial R&D." 27 firms

Of these:

a. The institution was a research institute	13
* At least one of the individuals involved was subsequently employed by firm doing the initial R&D	11

Of these,

5 became owners of that firm

4 were not owners but were doing R&D

* Reported source of basic knowledge or experience
that lead to the initial development;

5 reported a research institute

1 reported another manufacturing firm

6 reported the plant

1 was unknown

b. The institution was a 'parent' firm

4

* At least one of the individuals
involved was subsequently employed by
firm doing initial R&D

3

Of these,

1 became an owner of that firm

2 were not owners but were doing R&D

* Reported source of the basic knowledge or
experience that lead to the initial development;

3 reported a research institute

1 reported another manufacturing firm

c. The institution was another
manufacturing firm

10

* At least one of the individuals
involved was subsequently employed by

firm doing initial R&D

5

Of these

2 became an owner of that firm

1 was not an owner but was doing R&D

- * Reported source of the basic knowledge or experience that lead to the initial development;

2 reported a research institute

2 reported another manufacturing firm

5 reported in plant

1 was unknown

Details on group B. above.

"The institution is unknown, and the initial R&D occurred before, or at the same time as, the founding of the firm."

Of these

14 firms

- * At least one of the individuals involved was subsequently employed by firm doing initial R&D

13

Of these,

7 became an owner of that firm

4 were not owners but were doing R&D

- * Reported source of the basic knowledge or experience that lead to the initial development;

3 reported a research institute

3 reported another manufacturing firm
7 reported in plant
1 was unknown

Details on group C. above.

"At the firm doing the initial R&D" 17 firms

- * The individual's position in firm at the time of the development were as follows;
  - 8 were owners
  - 6 were not owners but in the R&D department
  - 3 were in other departments but not owners
- * Reported source of the basic knowledge or experience that lead to the initial development;
  - 0 reported a research institute
  - 8 reported another manufacturing firm
  - 9 reported in plant

Details on group D. above.

"Unknown". 25 firms

- * Current positions of individuals concerned are as follows;
  - 11 are owners of the firm which initiated the R&D
  - 14 are in the R&D department of that firm

* Reported source of the basic knowledge or
experience that led to the first development;

2 reported a research institute

4 reported another manufacturing firm

19 reported in plant

3. Investment in R&D

This section analyzes the responses to questions 3.7 to 3.10 of the questionnaire (pp. 81-82 in the report). Only 12% of the sample responded to question 3.7, the question designed to obtain information on sources of funding, so we do not analyze the responses to that question. The other three questions asked about the expenses involved in the first R&D project, the number of man years invested in that project, and the time (in months) from the beginning to the end of the development of the first project. We refer to these variables as SR, SLR, and TBD, respectively. Table 6 provides some summary statistics on the sampling distributions of these variables. On average firms in this sample invested about one quarter of a million dollars in their first project, took about 26 months to complete it, and used about five man years of labor in the process. The variance around these averages is quite large (the coefficients of variation for the investment variables were about 1.5), and all three of the variables are positively correlated (with correlation coefficients ranging from .5 to .68).

We looked to see if there were definite differences in distribution of the investment variables by some of the different discrete characteristics of the investment projects we had available from the replies to the other questions. Our search was not very successful, though there were some noticable (though only marginally significant) differences in the distributions by educational level for the first inventor. Recall that 79% of the

Table 6*

Summary of Investment Variables

Variable	Observations = response rate	Mean	Std. Dev.	Min	Max
SLR	77	4.66	6.79	1	35
SR	81	259.75	404.20	10	1500
TBD	77	25.65	20.06	2	99

* SLR = man years invested in first R&D project, SR = thousands of dollars invested in that project, and TBD = time from the beginning to the end of development of that project.

85 startups for which we had information on the educational level of the first inventor had a first inventor with either a graduate degree or/and engineering degree (the other 21% were about equally split between those with no formal education above a high school level, and those with a bachelors degree). The 27 projects for which the first inventor had a graduate degree and for which we had information on the investment variables tended to be more expensive, use more workers, and take longer to complete than the 29 projects for which the first inventor had an engineering degree (and we had information on the investment variables). This probably is indicative of a difference in the type of projects inventors with different educational backgrounds tend to work on (those with higher degrees working on projects which are somewhat more complicated and require somewhat more basic scientific breakthroughs for completion). Projects that started in firms that were founded at about the same time as the project started were also slightly smaller, and took slightly less time to develop, than other projects; a fact which probably reflects a relative advantage to existing (in contrast to newly founded) firms, in starting more expensive, time consuming projects. This could be due to either less costly access to finance capital (lower perceived default probabilities), or jointness in the production and marketing of the possible outputs from more costly projects.

We tried to fit several least squares linear 'investment equations' to our sample using various firm characteristics as 'independent' variables. On the whole our attempts did not resolve

much more than that the various investment variables (SR, SLR, and TD) were positively related to one other. Though for any given project we would expect to find a downward sloping (stochastic) trade-off between investment and time to completion of the project (see, for e.,g., Kamien and Schwartz, 1982), there are at least two reasons why we do not find it surprising that there is a positive correlation between TD and SLR in the cross-section. First, even if outcomes of research projects were deterministic, there is a large amount of heterogeneity in the degree of difficulty of the various projects, and the optimal development of the projects that are more difficult is likely to require both more time and more resources. Second, in a stochastic world of homogeneous projects, projects that take more time to complete will be those projects for which the early experiments were not as successful, and, which, therefore, required additional experiments and the associated resources.

Table 7 provides some typical results from linear regressions of SR and TBD against project and firm characteristics (the results using SLR as the dependent variable were even less sharp than the results reported for SR). Here DAO, EBA, EG, and EE are indicator variables taking the value of one if the first inventor was working outside of the firm, and if the inventor's educational level was a BA, graduate, or engineering degree, respectively. DA and DDE are indicator variables taking the value of one if there was no response to the question on the location of the inventor when the first developemnt was made, and on the educational level of the

TABLE 7

Regression Result for TBD and SR *

Panel A: Dependent Variable = TBD*

*Number of observations = 77

R-square = 0.1108

Root MSE = 19.851

Variable :	Coefficient	Std. Error	t	Mean
-----:-----				
DA :	.90	8.73	-0.10	.08
DAO :	2.30	5.26	0.44	.29
INWOR :	.01	.01	1.22	1 2 7 . 7 7
DDE :	6.00	21.25	0.28	.01
EBA :	19.35	10.87	1.78	.06
EG :	12.94	7.43	1.74	.39
EE :	4.44	7.34	0.61	.40
CONS :	15.64	6.37	2.46	1
-----				

* EBA, EG, EE, and DDE are dummy variables for the inventor having a BA, a graduate degree, an engineering degree and for not having information on the education of the inventor, respectively. DAO and DA are dummy variables for the workplace of the inventor at the time the initial development was made being outside the firm that did the subsequent R&D, and for there being no answer to this question, respectively. INWOR is the number of workers in the firm at the time it begins R&D activity.

Panel B: Dependent Variable = SR*

*Number of obs = 81

R-square = 0.2049

Root MSE = 377.31

Variable :	Coefficient	Std. Error	t	Mean

DA :	-68.97	165.57	-0.42	.07
DAO :	175.80	97.21	1.81	.28
INWOR :	.32	.15	2.08	124.41
DDE :	366.39	205.95	1.78	.06
EBA :	-63.68	191.84	-0.33	.07
EG :	-96.86	135.84	-0.71	.37
EE :	-129.65	135.08	-0.95	.36
CONS :	239.66	116.76	2.05	1
-----				

first inventor, respectively. INWOR measures the number of workers at the firm at the time the firm begins R&D activity. The results of the univariate analysis on TBD is confirmed in the multivariate analysis; the only variables which seem marginally significant in the TBD equation are the education variables. Only the size of the firm, and the indicator for the inventor being outside of the firm, are significant in the investment expenditure equation. The latter effect could be a result of either less costly access to finance capital, or of a selection in which larger firms tend to engage more in projects that require more investments; the effect of DAO seems to be indicating that projects relying on initial developments which took place outside of the firm tend to be more costly.

4. Indicators of the Success of the First R&D Project

This section is based on the answers to question 4.1 to 4.4 of the questionnaire (p. 82 of the report). The response rate to questions 4.2 to 4.4, the questions designed to get an indication of the rate of profit on the investments in the firms' research projects, was very low. As a result we have to suffice with an analysis of the responses to the question on the various qualitative indicators of success (question 4.1; a question which everyone responded to). This tells us whether the first R&D project lead to;

- a) a new product that was placed on the market

- b) a new process that was used by the firm
- c) a registered patent
- d) a completely new R&D project

We combine the indicator functions for the events described in a) and in b) and call it NEWP. The indicator function for the event in c) is called PATENT, and the indicator function for the event described in d) is called NEWRD. Table 8 provides the sampling distribution of NEWP and PATENT. 76 projects (76% of the sample) produced a new product or process, and 33 produced a new patent. 19 of the projects produced neither a new product nor a new patent, and 28 produced both. Again, we have to be cautious in interpreting these results since a firm which undertakes an unsuccessful R&D project is less likely to survive, and be caught by our sampling procedure. Thus the failure proportions reported here are probably downward biased estimates of the proportions failing among the population of all projects started.

Only 5 of the 33 patents are not NEWP, and these five were not followed by a NEWRD. Therefore we decided to use only two success indicators in the econometric analysis, NEWP and PATNEW, the latter being an indicator function for the event that both a new product (or process) and a new patent emanated from the project (PATNEW = 1 for 28 members of the sample).

Tables 9 and 10 provide the frequencies of NEWP and PATENT conditional on education and field of development. It is clear that the frequency of 'success' is significantly lower when the inventor has a graduate degree. Recall that projects emanating

Table 8

SAMPLE FREQUENCIES OF NEWP AND PATENT

NEWP	PATENT	0	1	TOTAL
0		19	5	24
1		48	28	76
TOTAL		67	33	100

Table 9

FREQUENCY TABLE OF SUCCESS/CONDITIONAL ON DEGREE OF THE INVENTOR

Education Known					Graduate Degree				
NEWP	PATENT	0	1	TOTAL	NEWP	PATENT	0	1	TOTAL
0		8	5	13	0		6	4	10
1		47	25	72	1		20	4	24
TOTAL		55	30	85	TOTAL		26	8	34

Engineering Degree					BA Degree				
NEWP	PATENT	0	1	TOTAL	NEWP	PATENT	0	1	TOTAL
0		2	0	2	0		6	1	1
1		18	13	31	1		1	5	6
TOTAL		20	13	33	TOTAL		1	6	7

from inventors with graduate degrees also tended to be both more costly, and more time consuming. A likely explanation of these findings is that the projects generated by inventors with graduate degrees tended to be more difficult, and that more difficult projects require more investments and have a lower probability of generating a marketable good or service. On the other hand, if these projects do manage to produce the good or service they were after, the product produced tends to be more profitable. In order to push this hypothesis further and investigate the trade-off curve between the private profitability of successful projects and the probability of success, we would need additional data on profits.

Table 10 provides success frequencies by field of R&D. The patent success frequency seems to be much higher in irrigation and plastics than in other fields, and the new product success somewhat lower than average in the biological fields. Table 11 provides success rates conditional on whether the firm was existing before it began R&D activity, or if the firm and its R&D department were founded at the same time (an event we associate with the firm being founded to exploit an R&D opportunity). The frequency of successful new products is higher for the projects that were started in new firms. Here again, however, we have to be very careful about the influence of the original sample selection criteria on our findings. Recall that we only sampled from firms existing in 1986. Older, more established, firms who began an R&D project that is not successful may well be more likely to survive than newborn firms who were established to exploit a research

Table 10

SUCCESS FREQUENCIES BY FIELD

FOOD STUFF ETC.

NEWP	PATENT	0	1	TOTAL
0		5	0	5
1		8	4	12
TOTAL		13	4	17

IRRIGATION AND PLASTICS

NEWP	PATENT	0	1	TOTAL
0		1	1	2
1		2	7	9
TOTAL		3	8	11

MACHINERY AND FOODS

NEWP	PATENT	0	1	TOTAL
0		5	1	6
1		25	13	38
TOTAL:		30	14	44

BIOLOGY

NEWP	PATENT	0	1	TOTAL
0		7	3	10
1		10	3	13
TOTAL:		17	6	23

Note: The division to fields is given in the Appendix

Table 11

Frequency of Success Conditional on The Timing of R&D

All Cases That Have Timing Information

NEWP	PATENT	0	1	TOTAL
0		12	2	14
1		27	20	47
TOTAL:		39	22	61

R&D Before The Firm Is Established

NEWP	PATENT	0	1	TOTAL
0		4	0	4
1		14	11	25
TOTAL:		18	11	29

R&D After The Firm Is Established

NEWP	PATENT	0	1	TOTAL
0		8	2	10
1		13	9	22
TOTAL:		21	11	32

opportunity that failed. This point makes clear the need for an estimable structural model of R&D activity that endogenously accounts for liquidation possibilities, but to estimate such a model we would require a longer, and larger, panel.

We have tried several different probit (and logit) models for the probability of each of the indicator functions, NEWP and PATNEW. The probability models had various characteristics of the firms or the projects at the time the project was initiated as 'independent' variables, as well as, in some runs, investment expenditures. Table 12 provides results from typical runs. It indicates that the frequency of $PATNEW = 1$ is significantly increased if the inventor has a BA degree, if the basic knowledge of the inventor was obtained at another manufacturing firm in Israel (there is also a slight positive effect if the basic knowledge is obtained at an Israeli research institute), and in situations where the time from the beginning to the end of the project was larger. This frequency was decreased if the inventor had a graduate degree. The inclusion of other variables in the specification did not alter the results as described in the run in the table. On the other hand, the frequency of $NEWP = 1$ does not vary significantly with any of the state variables we collected in our study, excepting whether the inventor had a graduate degree (the effect of the graduate degree being negative in this equation also). This points to the possibility that projects associated with an individual with a graduate degree are more risky, in the sense that they are less likely to generate any marketable good or

Table 12

Probit Estimates for Success Variables:

PATNEW and NEWP*

Probit Estimates: Dependent Variable = PATNEW

Number of obs = 100

Chi2(11) = 34.91

Log Likelihood = 41.839885

Prob > chi2 = 0.0003

Variable	:	Coefficient	Std. Error	t	Mean
TBD	:	.04	.01	3.03	249.52
DTBD*	:	-40.33	13.44	-3.00	.23
SLR	:	-.05	.04	-1.34	3.59
DSLRL*	:	-1.57	1.12	-1.41	.23
DDE*	:	.89	.89	1.00	.15
EG	:	-1.46	.48	-3.05	.34
EBA	:	1.53	.71	2.15	.07
DDBK*	:	.17	1.09	0.16	.18
BKP	:	.63	.56	1.13	.54
BKRI	:	1.04	.64	1.63	.14
BKMI	:	1.38	.58	2.40	.14
CONS	:	-1.77	.63	-2.83	1

Table continued on next page

Probit Estimates: Dependent Variable = NEWP

Number of obs = 100

Log Likelihood = -34.649981

chi2(10) = 40.92

Prob > chi2 = 0.0000

Variable	:	Coefficient	Std. Error	t	Mean
TBD	:	-0.01	.01	-0.49	249.52
DTBD*	:	6.77	13.31	0.51	.23
SLR	:	.11	.10	1.11	3.59
DSLRL*	:	-.88	.69	-1.26	.23
DDE*	:	-1.54	.69	-2.23	.15
EG	:	-1.17	.42	-2.80	.34
EBA	:	-.21	.80	-0.26	.07
AR	:	-.22	.40	-0.55	.37
DAO	:	.18	.42	0.44	.27
DA*	:	-.42	.55	-0.77	.17
CONS	:	1.72	.51	3.37	1

*bkr, bkri, adbkri, indicates whether the basic knowledge and experience that underlie the first development, was acquired at the plant in which he worked, at a research institution, or at another manufacturing firm, respectively. Starred variables indicate the presence of data on a right hand side variable. All other variables are defined in the text.

service as well as being more costly and taking more time to complete. If this were true, we would expect such projects to be more profitable if successful. However, in order to come to an understanding about the profitability of the projects studied, and the trade offs in the determinants of that profitability, we would require more detailed answers to our profitability questions.

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Israel's Agricultural Invention:

An International Analysis

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Israel is emerging as both an important market for inventions originating in other countries and as an important supplier of inventions to other countries. Inventors in Israel are obtaining a significant number of patents for agricultural inventions and, in contrast to almost all developing countries, Israel is obtaining a large number of patents in other countries. Israeli inventors are active in the new fields of biotechnology invention and show promise of being quite important suppliers and sellers of this technology.

In this paper, Israel's invention is analyzed from an international perspective. In Part I a comparison of legal systems protecting and stimulating inventions, including Israel's, is undertaken. In Part II, Israel's agricultural invention for 17 fields of agricultural technology is summarized for the 1973-77, 1978-82 and 1983-87 periods. Part ~~II~~ then reports a comparative summary of Israel's invention with a number of other developing and newly industrializing countries. The final section of the paper summarizes these data and compares them to the survey data produced by the BARD project.

I. Legal Systems for Agricultural Invention: A Comparative Survey

A. Types of Invention

The term "invention" broadly covers any new process, device, chemical composition, or thing which has been developed, devised, or discovered. Although every invention has different economic effects and origins, inventions stemming from agricultural research can be generally grouped as follows: (i) mechanical/electrical; (ii) chemical; (iii) biogenetic; and (iv) other.

Mechanical/electrical inventions primarily include new machinery for planting, cultivating and harvesting agricultural crops, as well as new machinery and equipment used in animal husbandry. These inventions frequently require small, but nevertheless patentable, modifications in order to be transferred from one region to another. Mechanical/electrical inventions also include processes for making and/or using such machinery.

Chemical inventions include fertilizers, herbicides, insecticides, and pharmaceuticals for animals. These inventions are usually more adaptable than are mechanical/electrical inventions. However, there is a great deal of research conducted to find new pesticides and herbicides that meet local conditions and regulations, and, ironically, that replace older chemicals to which the pests themselves have adapted.

Biogenetic inventions include improved plant varieties and animal breeds, the products of the new bioengineering processes such as recombinant DNA technology, and such processes themselves. The products of biogenetic research, especially plants, are usually quite limited in their geographic adaptability due to varying soil and climatic conditions, as the large and increasing number of corn and soybean varieties planted in the United States attests.

An invention patent system, which governs the usual type of patent, gives the inventor the right to exclude others from practicing the invention for a certain time period (usually 15-20 years). Invention patent systems traditionally require that an application for a patent must include an "enabling disclosure" which sufficiently describes the invention so that others skilled in the same technical field can reproduce it successfully. Patent laws thus encourage early publication of the invention in return for granting a limited monopoly. (From the perspective of economic efficiency, such disclosure is preferable to trade secrecy.)

An invention patent is not an exclusive right to practice a particular invention, but rather a right to exclude others from practicing the invention, within the scope of the exclusion defined by the claims which describe the novel contributions made by the inventor.

To be valid, an invention patent must disclose an invention that is novel, useful, and an improvement over the prior art. An invention must be novel in the sense that it has not previously been published, exhibited, or otherwise described, except within the period immediately preceding the application, and then only by the applicant. As to its utility, the invention must be capable of industrial or agricultural application, and not be purely ornamental.

The degree of "improvement over prior art" that an invention must exhibit defines the single most important attribute of a patent system. Also called the "inventive step" or "level of invention" requirement, this increment must be greater than what would be obvious to the average person skilled in the art. The height of this step varies from country to country.

Utility models or "petty patents" are similar to invention patents in that they give the inventor the right to exclude others from practicing the invention for some period of time. They differ from the invention patents in requiring only novelty and utility, without any "inventive step" above the

prior art. Thus, petty patents preserve rights to minor variations of known devices rather than to major technical innovations having broad adaptability. Countries usually grant petty patent protection for a much more limited time than is the case for invention patents, and usually grant petty patents only to their own citizens. Also, since the existence of an inventive step need not be determined, such systems cost less to administer than do most invention patent systems. It is easy to see that petty patent systems tend to stimulate domestic invention. In developing countries, minor adaptations of machinery and other inventions to accommodate local conditions help the local economy but may not be valuable abroad. Nationals of these countries are more likely, therefore, to utilize petty patents rather than the more costly and difficult-to-obtain invention patents.

An inventor's certificate is a notice given in socialist countries that entitles an inventor to receive compensation for his invention, which as a matter of property belongs to the state. This non-market alternative to the standard patent aims to reward the inventor while removing his monopolistic control over the invention.

Industrial design patents provide protection to designs as opposed to inventions per se. They provide weak protection somewhat similar to that provided by copyrights.

Analogous to invention patent systems, plant patent and variety protection systems provide breeders and developers with limited rights to exclude others from commercializing new plant varieties they have developed. A plant variety must establish novelty by exhibiting uniformity, stability, and distinctness from all known varieties. Typically, some type of control depository is provided to preserve seed samples for the plant varieties being protected, in addition to the requirements for verbal and pictorial description. To encourage

the use of the protected varieties in further breeding/research programs, most plant protection laws exempt experimental breeding from infringement claims. Also, other provisions may be included, such as in the United States system, which permits farmers to save seed from their crop for their own use on their farm and to sell it to other farmers, for purposes other than seed reproduction.

C. The Role of International Conventions

In keeping with the treatment of inventions as "intellectual property," most countries of the world are party to at least one international agreement, the intent of which is to protect an inventor's rights to his invention from country to country, much in the same way that free trade agreements protect commerce from tariffs and other unilateral restrictions. The most widely held of these agreements is the International Convention for the Protection of Industrial Property, usually called the "Paris Convention" for the seat of its first formulation in 1883. This agreement, as subsequently amended at The Hague (1925), London (1934), Lisbon (1958), and Stockholm (1967), provides that any country belonging to the convention should grant to citizens of another convention country the same rights as those belonging to its own citizens.

The next logical step in providing uniform protection for citizens of different countries is to create a uniform application system under which a single application may be examined by designated member countries according to their particular laws. An agreement of this type was signed by 35 countries in 1978. Called the Patent Cooperation Treaty, its stated aims are "to make a contribution to the progress of science and technology," "to perfect the legal protection of inventions," "to simplify and render more economical the obtaining of protection for inventions where protection is sought in several countries," "to facilitate and accelerate access by the public to the technical

information contained in documents describing new inventions," and "to foster and accelerate the economic development of developing countries through the adoption of measures designed to increase the efficiency of their legal systems...."

About half of the parties to the Patent Cooperation Treaty are developing countries: Algeria, Argentina, Brazil, Egypt, Iran, Israel, Madagascar, Malawi, North Korea, the Philippines, Sri Lanka, Syria, along with the following members of the African Intellectual Property Organization: Cameroon, Central African Republic, Chad, Congo, Ivory Coast, Senegal, and Togo. The remainder comprises Western Europe, North America, Japan, and half of Eastern Europe. With the exception of the Philippines, North Korea, and Sri Lanka, underdeveloped Asia is missing entirely. Latin America, too, has few participants. We may ascribe the relatively strong rate of participation by African countries to the formation of the African Intellectual Property Organization (open to any country but presently comprising former French colonies), a group of countries which binds its members by a modern agreement modeled on French patent law.

Two other treaties have a more direct bearing on agricultural inventions: the International Convention for the Protection of New Varieties of Plants, and the Budapest Treaty on the International Recognition of the Deposit of Microorganisms for the Purpose of Patent Procedure. The first of these, the Plant Variety Convention, was amended most recently in 1978 and provides for patent or patent-like protection to breeders of new plant varieties who belong to member countries. These plants may be sexually as well as asexually reproduced (which gives protection to hybrid varieties), but member states may exclude hybrid varieties from protection at their discretion (on the grounds that the breeder retains control over the parents, which renders protection

unnecessary). At present, no developing country belongs to this treaty, and only one, Argentina, has passed a law to give protection to new varieties.

The Budapest Treaty on Microorganisms was signed in 1977. It provides for an "international depository authority" in several nations, which keeps samples of patented microorganisms. This special arrangement takes the place of the usual written and/or graphic description that regular patent documents employ. The treaty aims to lower the cost and reduce the inconvenience of trying to deposit multiple samples in each country in which the inventor desires protection.

The treaty does not grant patent protection per se, but merely commits states to the system of recognizing deposits made in other countries as equally valid with those made in its own. Thus, the treaty leaves a considerable degree of freedom in the hands of the individual countries to decide what constitutes a patentable microorganism. Among developing countries, only Senegal, Korea and the Philippines belong to this agreement; the only other non-Western participant is the Soviet Union.

D. Comparative Summary of Agricultural IPR's

In order to summarize concisely the scope of protectable subject matter in the various countries assume a hypothetical Amalgamated Agricultural Research Corporation (AARC). AARC's agricultural research program covers the entire spectrum of research and development activities. For the purpose of this discussion, we assume that all of these research results were obtained exclusively by AARC using AARC funds, were never before existent or described anywhere in the world, and were in fact better than the state of the art.

Mechanical/Electrical Inventions

1. AARC Plough I: a basic innovation in ploughs which is adaptable to a wide range of soil and climatic conditions.
2. AARC Plough II: a minor modification for adapting a plough to be utilized in a specific localized soil condition.

3. AARC Chemical Fertilizer: a new fertilizer chemical compound which optimizes tolerance to extremes in soil moisture conditions.
4. AARC Insecticide: a new and useful chemical compound insecticide.
5. AARC Herbicide: a new and useful chemical compound herbicide.
6. AARC Pharmaceutical for Animals: a chemical compound pharmaceutical for controlling disease in farm animals.

Biogenetic Inventions

7. AARC Soybean: a new improved soybean variety developed in a plant breeding program.
8. AARC Corn: a new hybrid corn seed variety developed in a plant breeding program, with AARC retaining control over the hybrid parents.
9. AARC Rose: a new variety of asexually reproducible ornamental rose.
10. AARC Beef Cattle: a new pure breed of beef cattle developed in a selective breeding program.
11. AARC Bacterium: a new and improved nitrogen-fixing strain of bacteria developed using recombinant DNA techniques.
12. AARC Live Virus Vaccine: a new strain of virus to be used as a vaccine for animals, developed using recombinant DNA techniques.

Other Inventions

13. AARC Computer Program: a new and improved computer program that determines the optimal mix of chemicals in the AARC Chemical Fertilizer (invention #3).
14. AARC Accounting System: a new and improved accounting system used for optimally allocating the research personnel and facilities in the various research projects, adaptable to any large agricultural research organization.

From Figure 1, one can see immediately that the degree of protection given to agricultural intellectual property varies considerably among countries. Of particular interest are those entries that denote that the device in question is specifically prohibited from being patented. Agriculture is somewhat peculiar among traditional production industries in that many agricultural inventions are either ineligible for protection or have an indeterminate status under most national patent acts.

Country	Mechanical/ Electrical		Chemical				Biogenic						Other	
	Plough I Major	Plough II Minor	Fertilizer	Insecticide	Herbicide	Chemical Vaccine	Boycott	Corn Hybrid	Rose	Beef Cattle	Nitrogen- Fixing Bacteria	Live Virus Vaccine	Computer Program	Accounting System
U.S.A.	yes	no	yes	yes	yes	yes	yes	no	yes	no	yes	yes	no	no
Asia														
Bangladesh 1,2	no	no	no	no	no	no	no	no	no	no	?	?	no	no
India	no	no	no	no	no	no	no	no	no	no	no	no	no	no
Indonesia 2	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Korea (South)	yes	yes	no	no	no	no	no	no	yes	no	yes	no	no	no
Malaysia 1,2	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Nepal 4	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Pakistan 3	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Philippines 5	yes	yes	yes	yes	yes	no	no	no	no	no	yes	yes	yes	no
Singapore 1,3	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Sri Lanka 3	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Taiwan	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no
Thailand	no	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Latin America														
Argentina	yes	no	yes	yes	yes	no	yes	yes	yes	no	yes	no	no	no
Bolivia	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Brazil	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no
Chile	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Colombia	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Costa Rica	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Dominican Rep.	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Ecuador 7	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Guyana	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	yes	no
Haiti 5	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Jamaica	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Mexico	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Nicaragua	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Panama 5	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Paraguay	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Peru	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Suriname	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Uruguay	yes	yes	no	no	no	no	no	no	no	no	no	no	no	no
Venezuela	yes	no	no	no	no	no	no	no	no	no	no	no	yes	no
West and Middle East														
Algeria	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Bahrain 1	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Egypt	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Iran	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Iraq	yes	no	yes	yes	yes	no	no	no	no	no	no	no	yes	no
Israel	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Jordan	yes	no	yes	yes	yes	yes	no	no	no	no	yes	yes	no	no
Kuwait	yes	no	yes	yes	yes	no	no	no	no	no	yes	yes	yes	no
Lebanon	yes	no	yes	yes	yes	no	no	no	no	no	no	no	yes	no
Syria	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Africa														
African Intellectual Property Organ- ization 1,6	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Algeria 1,7	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Botswana														
Lesotho 3	yes	no	no	no	no	no	no	no	no	no	no	no	no	no
Madagascar														
Mali 5	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Chad 3	yes	no	yes	yes	yes	no	no	no	no	no	no	no	no	no
Kenya 3	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Liberia	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Libya	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Malawi														
Zambia														
Maldives 8	yes	no	yes	yes	yes	yes	no	no	no	no	yes	no	yes	no
Nigeria 1	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Sierra Leone 3	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
S.W. Africa 5	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Sudan	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Tanzania	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no
Tunisia	yes	no	yes	yes	yes	yes	no	no	no	no	no	no	no	no

*This invention is specifically excluded from patent protection by national law.

*Although this chemical substance is specifically excluded from patent protection by national law, the process used to produce the substance is not excluded.

NOTES: This table summarizes the data that record the principal constituents of each country's patent laws.

1. British patent law is assumed to hold in this country, owing to the provisions in its laws. British patent applications (whether or not by British citizens) have priority. In practice, a prior British patent is routinely granted approval in this country at the applicant's request. We refer the reader to chapter 32 of the Patents Act of 1977 of Great Britain. The U.K. prohibits the patenting of microbial processes or products for use on humans or animals. Ghana independently prohibits patents on pharmaceutical and medical substances.
2. This country has no patent act of its own.
3. "Microbiological processes and the products of such processes" are patentable. Whether this protection extends to microorganisms *per se* is not known and will depend on the interpretations of the domestic courts. In the absence of specific indications to the contrary, we have assumed that the nitrogen-fixing bacteria and the live virus vaccine are not patentable under these circumstances.
4. A patent is granted to a foreign inventor if he has obtained a patent in his own country and any three other countries. Presumably, patentability standards in those countries apply.
5. Other than meeting public standards of health and morality, no other criteria for patentability are cited. In general, we take mechanical, chemical, and electrical inventions to be patentable, and others to be unpatentable. In the Philippines, U.S. law is assumed.
6. The following countries are signatories to the Libreville Agreement of 1962, which establishes a regional Intellectual Property Office: Benin (Dahomey), Cameroon, Central African Republic, Chad, Congo, Gabon, Ivory Coast, Madagascar, Malagasy Republic, Mauritania, Niger, Senegal, Togo, and Togo. In the absence of laws to the contrary, we apply the revised standards to the other countries as well.
7. The inventor is entitled to state indemnification for the rights to some or all of these inventions. In this case, he does not own the rights himself.
8. Food and chemical patents require mandatory licensing.

As one can see from Figure 1, several countries ban the patenting of chemical substances and the processes for making them; others ban only the substances; still others permit chemicals in general to be patented but do not allow chemical vaccines to be patented because they are medicines. Among Asian countries, India, Korea, and Taiwan do not allow chemical patents of any kind; Thailand excludes only chemical medicines. (Thailand is currently changing its laws.) As a group, Asia falls midway between Latin America and Africa in allowing chemical patents. In Latin America, half of all countries ban patents on chemicals of any type, and three-fourths of them ban patents on chemical medicines. By contrast, all the African countries permit some kind of chemical patent, and only two exclude chemical medicines from protection. In the Middle and Near East, all countries allow non-medicinal chemical patents, but most forbid patents on medicinal chemicals. Israel is one of the few that permits this type of protection.

For Plough II-type inventions (those which do not meet the "inventive step" requirement of a regular patent, but which contain some adaptation or modification of existing technology), five semi-industrialized countries provide protection via a utility model system: Brazil, Uruguay, Korea, the Philippines, and Taiwan, as well as the parties to the African Intellectual Property Organization.

As to biogenetic inventions, most countries specifically exclude plant varieties and animal species from protection, either as such or by excluding foodstuffs. Among developing countries, only Argentina and Korea make provision for plants of any kind to be patented, and only Argentina permits sexually-reproduced plants to be patented. The U.S. does not provide plant variety protection for the hybrid corn--presumably because such protection is not needed, since corn breeders can effectively maintain control over the

hybrid parents, and thus they already have so-called "genetic" protection. However, recent strengthening of the U.S. system probably allow the patenting of plants. Although there are legal systems in some countries (e.g., Hungary and Romania) which provide breeder's rights to new animal breeds, none of the countries listed in Figure 1 has such a provision, so none of them would protect AARC's new strain of beef cattle.

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The exemplary "other inventions," namely the computer program and the accounting system, do not generally receive patent protection or the like under any of the legal systems. A copyright system which included computer programs might, however, provide some limited protection. Recently, however, this pattern has been broken. In a 1983 survey the following countries indicated

that they gave patent protection to computer programs: Ecuador, Iran, Japan, Jordan, Kuwait, Pakistan, Syria, and Uruguay. Curiously, developed countries appear to lag behind developing countries in adopting this broader view of intellectual property protection (see Baxter, vol. 2A, pp. 232.22-232.25).

Except for the exclusion of patents on plant varieties, Israel's laws permit a very broad spectrum of inventions to be patented. Most of its neighbors do not permit the patenting of chemical vaccines, but Israel does. Unlike most countries, Israel's laws do appear to permit the patenting of the nitrogen-fixing bacteria and the live-virus vaccine. The rapid growth in these areas of biotechnology will be demonstrated in Parts II and III, especially in Tables 8A and 8B. This evidence gives additional credence to the view that Israel's patent laws are among the most progressive. It also indicates indirectly that, unlike many countries outside the OECD, patent protection is enforceable in the Israeli judicial system.

In contrast, India forbids the patenting of "a method of agriculture or horticulture"; "any process for the medicinal, surgical, curative, prophylactic, or other treatment of human beings or any process for a similar treatment of animals or plants to render them free of disease or to increase their economic value or that of their products"; or any substance "intended for use, or capable of being used, as food or medicine or drug" [Article 3(h)], (i); Article 5(a)]. Furthermore, "medicine or drug" includes "insecticides, gericides, fungicides, weedicides and all other substances intended to be used for the protection or preservation of plants" [Article 2(1)(iv)].

The Indian law illustrates a general pattern in developing countries. The argument for such laws is that food and medicine products are "basic needs" and that citizens in less developed countries should not be vulnerable to the monopoly pricing associated with patents. This argument presumes that a

country like India would lower the total cost of producing technology were it to abandon its patent system. This policy option is further considered in Part IV.

In recent years the developed countries have taken steps to broaden and strengthen the protection afforded to intellectual property generally and to biotechnology in particular. For example, the so-called "Chakrabarty decision" of the U.S. Supreme Court overruled the U.S. Patent Office by permitting microorganisms to be patentable subject matter. In this and many other areas that bear on the protection of biotechnology, the central issue is that patents have traditionally been obtainable only for man-made inventions, not for "naturally" occurring subject matter, which belongs in the public domain. The argument in favor of extending protection, of course, is that the processes, substances and organisms that fall under the rubric of biotechnology do not occur naturally, or, if the substance also occurs naturally, the process used to produce it in commercial quantities is man-made.

The counter-arguments to the protection of biotechnology are not trivial, however. Traditional intellectual property theory distinguishes between two concepts of invention that are confounded in everyday usage. "Invention" can refer both to the information that an individual has discovered, and to the device that embodies that information in a unique way. A patent right gives its owner the power to prevent someone else from making, using or selling the device; in order to receive this right, the discoverer must relinquish all claims to the ownership of the information. In particular, another inventor who wishes to use the information in order to improve further the technology has an unrestricted right to do so, even to the point of being able to make the device itself if its use is for experimental rather than commercial purposes.

In most contexts, this conceptual distinction is reasonably clear. The patent document contains the information about how to make the device; it is not the device itself, however. In the case of biotechnology, the distinction may be harder to draw. For example, most plant variety protection laws specifically permit the experimental use by others of the protected variety, in order to encourage subsequent invention. But in this case, "experimental use" implies not only access to and use of the incremental discovery made by the inventor, but to the seed, i.e., to the "device" itself. On the other hand, the seed contains much genetic "information" that does occur naturally and to which the inventor makes no claim. Because the device frequently cannot be separated from the information, a conflict between the public's right to the information (both newly discovered and naturally occurring), and the inventor's right to the device, arises.

An added complication, one with more ethical than legal implications, is that biotechnology inventions may involve living organisms rather than simply substances and processes. An extensive review of the difficulties posed by the ownership of breeds and strains remains beyond the scope of this discussion. The subject will reappear shortly, however, in the discussion of the legal conflicts between the developed and developing worlds.

Because of the conceptual difficulties posed by giving patent and variety protection to biotechnology, the World Intellectual Property Organization, a U.N. agency, has convened a Committee of Experts on Biotechnological Inventions and Industrial Property. The third session of this committee, held in June-July 1987, discussed the results of a questionnaire that it had circulated among various patent offices and non-governmental agencies. The questionnaire dealt with the patentability of various types of biotechnological inventions and various possible objections to extending patent protection. The issues

raised concern somewhat technical features of patent protection, such as industrial applicability of the product, the lack of repeatability in reproducing the product, problems of living matter, and problems concerning the distinction between "discoveries" (natural laws and properties, which are not patentable under the Geneva Treaty on the International Recognition of Scientific Discoveries), and inventions per se.

For the purposes of the present discussion, it is worth noting the general features of the committee's debates and recommendations. First, only developed countries appeared to be in a position, in terms of both legal and technical competence, to answer satisfactorily the questionnaire. Outside the OECD, the only responses came from other West and East European countries and the Soviet Union. This underscores the fact that even the most advanced developing countries have difficulty assembling the expertise necessary to grapple with the intellectual property issues; consequently, they also lack effective input into the international policy-making process. Second, the responses showed a fair degree of heterogeneity and uncertainty as to the possibilities for patent protection or infringement in various situations. Third, the report of the Committee of Experts contained recommendations that favor greatly expanding the protection available for biotechnology inventions, and interpreting as restrictively as possible the objections to patentability that are usually raised. For example, with regard to living matter, the Committee stated, "A product should not be excluded from patent protection for the reason ly that it may be considered as living matter or as containing living matter" (see WIPO Report BioT/III/2 and Annexes). As might be expected, this position was welcomed by those countries with the most advanced biotechnology capabilities, i.e., the U.K. and the U.S. Fourth, of the few developing countries to attend the session (Brazil, Cuba, Ghana, India,

Indonesia, Madagascar, Mexico, Korea, Saudi Arabia, and Turkey), most welcomed the discussion of the issues, but most hesitated to endorse the expansion of intellectual property rights for biotechnology. For example, the Indian delegation took pains to note its awareness of the importance of biotechnology issues and the fact that it had established a National Biotechnology Board in 1983. As part of its patent policy, however, India specifically excludes from protection any process for the medicinal, surgical, curative, prophylactic or other treatment of human beings, or any process for a similar treatment of animals or plants. These exclusions encompass a large share of agricultural inventions. It also appeared to be the case that the developing countries were much more concerned with the ethical issues surrounding intellectual property protection of biotechnology than were the developed countries.

This split between the developed and developing worlds parallels that which has emerged in many other contexts, notably in the Conference on the Law of the Sea Treaty, in which the developing countries took the position that the ocean seabeds represent part of "the common heritage of mankind." A directly analogous argument is made for the public availability of higher life forms and improvements in them. The developed countries generally favor the possibility for private exploitation of resources on efficiency grounds and point to the public benefits that result. In more traditional areas of patent protection, developing countries are much more likely than developed countries to exclude medical and agricultural inventions from protection, on similar grounds. One effect of this exclusion has been to remove key incentives for the improvement of such technology in these countries, however.

The trend towards expanded protection for biotechnology products and processes has continued more or less without interruption during the 1980s. The U.S. Patent and Trademark Office recently decided to grant its first patent

on a higher life form, a genetically altered mouse. In the short term, these events do not have many consequences for most developing countries; since they are generally not sophisticated enough either to pirate the technology or to modify it for their own use, these inventions have many of the same features as trade secrets.

Events indicate, however, that the developed world is prepared to press hard for protection in cases where piracy is a possibility, either because of indigenous adaptive capacity or because of infringing products exported to the market from other developed countries. For example, the United States recently completed a so-called "Section 301" action against Korea, in which it threatened trade sanctions if South Korea did not undertake an extensive revision of its intellectual property laws (covering copyright and well as patent laws). Among the results of the subsequent bilateral consultations was Korea's announced intent to accede to the Budapest Treat on the Protection of Microorganisms and to grant and enforce protection for agricultural chemical and pharmaceutical patents. Under recently enacted amendments to U.S. trade laws, patent infringement is deemed a per se "burden or restriction on commerce" and sets in motion a series of events that culminate in trade retaliation. More generally, intellectual property protection has become a central issue at the current Uruguay Round of talks of the GATT. The emerging conflict appears to be between advanced developing countries with significant adaptive capacity, such as Brazil and India, who argue that GATT is an inappropriate forum for the debate (they prefer WIPO), and the developed countries who claim to be losing billions of dollars a year to pirates. There is every reason to think that this division of interests will be even more sharp for science-based inventions like biotechnology, where the developed countries have very strong comparative advantage.

It may fairly be argued that the current international patent regime works to the disadvantage of those countries with the ability to copy inventions and who receive nothing in return for protecting the inventions from developed countries. On the other hand, some technologies must not merely be copied, but must be modified for local circumstances; this requires more than imitative ability. Agricultural inventions rank high on the list of technologies with a low degree of transferability, as we show in our quantitative summary of invention in the next section. Agricultural inventions, especially those that are biologically based, must be suited to the particular set of climatic and geophysical conditions in which they are to be used. Thus, if a developing country fails to grant patent protection to developed countries, yet lacks the capacity to modify the developed country inventions for its own conditions, it runs the very strong risk that no technology will be developed that will be locally suitable, and its productivity growth will stagnate. Our data show that biotechnology inventions generally seem to be somewhat more transferable than horticultural inventions, though somewhat less transferable than agricultural chemicals. Biotechnology inventions pertaining to agriculture, however, are likely to have many of the same limitations to transfer that more traditional technologies have, with similar consequences for the failure to permit patent protection of locally suitable invention.

II. Israel's Agricultural Invention at Home and Abroad

In this section we turn to data from the International Patent Documentation Center (INPADOC) data set to examine patents granted by year of grant for 17 fields of agricultural invention. The 17 fields of invention were

defined by detailed examination of the International Patent Classification system (IPC) definitions.

The data are reported in Tables 1-17 and will be discussed by field. Table 18 provides an overall summary. Each of the basic tables reports two sets of data. The upper panel reports the number of patents granted in each period in Israel by country of priority (i.e., the country of origin of the invention). The second panel reports the number of patents obtained by Israeli inventors in other countries (i.e., Israel is the country of priority or origin).

A. Crop Production Fields

Tables 1, 2 and 3 report inventions in planting machines, soil working machines and harvesting machines. Patenting patterns in these closely related agricultural machinery fields are quite similar. In each case, Israeli inventors obtain by far the largest number of inventions in Israel. They do not, however, seek many patents abroad, just as few foreign inventors seek patents in Israel. One principle reason for this is that agricultural machinery must generally be closely adapted to the local soil conditions, crops, cropping patterns, and factor price ratios. In other words, the transferability of agricultural machinery technology across geoclimatic boundaries is rather low.

After a lull during the late 1970s, (when, among other factors, the rapid increase in oil prices introduced a great deal of uncertainty into research on technologies dependent on fossil fuels, and made the use of these technologies much more expensive), agricultural machinery patent in Israel has generally expanded, especially among harvesting inventions. Patenting by foreigners also shows a sharp increase among harvesting inventions during this period, with the United States being the main foreign recipient of Israeli patents.

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PLANTING

Table 1

TABLE 1A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	10	14	22	46
UNITED STATES	5	2	3	10
GREAT BRITAIN	4	1	4	9
AUSTRIA	5	.	.	5
FRANCE	.	2	3	5
CANADA	3	.	.	3
SPAIN	.	.	2	2
AUSTRALIA	.	1	.	1
ITALY	.	1	.	1
MEXICO	1	.	.	1
NETHERLANDS	.	.	1	1
SOUTH AFRICA	.	1	.	1
WEST GERMANY	.	.	1	1
-----	---	---	---	---
TOTAL	28	22	36	86

TABLE 1B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN	.	.	3	3
AUSTRALIA	.	2	.	2
NETHERLANDS	1	.	1	2
WEST GERMANY	.	1	1	2
JAPAN	1	.	.	1
SOUTH AFRICA	1	.	.	1
-----	---	---	---	---
TOTAL	3	3	5	11

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF SOIL WORKING

Table 2

TABLE 2A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	12	13	17	42
UNITED STATES	7	1	.	8
AUSTRALIA	1	1	1	3
NETHERLANDS	3	.	.	3
NEW ZEALAND	2	.	.	2
ITALY	.	.	1	1
SOUTH AFRICA	.	1	.	1
SWITZERLAND	1	.	.	1
WEST GERMANY	.	1	.	1
-----	---	---	---	---
TOTAL	26	17	19	62

TABLE 2B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
SOUTH AFRICA	1	1	1	3
AUSTRALIA	.	.	2	2
FRANCE	1	1	.	2
GREAT BRITAIN	1	1	.	2
ITALY	2	.	.	2
PORTUGAL	.	.	2	2
SPAIN	2	.	.	2
UNITED STATES	1	.	1	2
WEST GERMANY	1	.	.	1
-----	---	---	---	---
TOTAL	9	3	6	18

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
 AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
 FOR 1973-77, 1978-82 AND 1983-87
 IN THE FIELD OF HARVESTING

Table 3

TABLE 3A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	6	22	47	75
UNITED STATES	4	5	16	25
ITALY	1	2	2	5
GREAT BRITAIN	1	.	1	2
NETHERLANDS	2	.	.	2
AUSTRALIA	.	.	1	1
FRANCE	.	.	1	1
WEST GERMANY	1	.	.	1
-----	---	---	---	---
TOTAL	15	29	68	112

TABLE 3B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	1	1	6	8
GREAT BRITAIN	.	.	5	5
ITALY	3	.	1	4
SOUTH AFRICA	.	.	3	3
AUSTRALIA	.	.	2	2
WEST GERMANY	.	.	2	2
SPAIN	1	.	.	1
-----	---	---	---	---
TOTAL	5	1	19	25

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF HORTICULTURE

Table 4

TABLE 4A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	60	78	82	220
UNITED STATES	17	25	26	68
FRANCE	19	9	3	31
WEST GERMANY	11	5	6	22
GREAT BRITAIN	4	7	6	17
ITALY	7	4	2	13
JAPAN	5	3	2	10
SWITZERLAND	1	7	2	10
SWEDEN	1	4	4	9
AUSTRIA	2	5	1	8
AUSTRALIA	1	3	2	6
MEXICO	2	3	1	6
NETHERLANDS	1	3	.	4
NEW ZEALAND	.	.	3	3
UNKNOWN	3	.	.	3
IRELAND	.	2	.	2
SOUTH AFRICA	1	.	1	2
ARGENTINA	.	1	.	1
BRAZIL	.	.	1	1
NORWAY	.	.	1	1
PORTUGAL	1	.	.	1
SPAIN	.	.	1	1
TOTAL	136	159	144	439

TABLE 4B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
AUSTRALIA	6	22	21	49
SPAIN	5	12	29	46
FRANCE	10	15	9	34
ITALY	3	6	15	24
WEST GERMANY	9	9	5	23
GREAT BRITAIN	1	11	8	20
UNITED STATES	3	9	7	19
SOUTH AFRICA	.	7	7	14
JAPAN	4	4	5	13
BRAZIL	4	3	2	9
NETHERLANDS	.	5	3	8
PORTUGAL	.	3	4	7
ARGENTINA	1	4	.	5
DENMARK	.	2	2	4
AUSTRIA	1	1	1	3
CANADA	.	2	1	3
MEXICO	.	.	3	3
NORWAY	.	2	1	3
BELGIUM	.	1	.	1
NEW ZEALAND	.	.	1	1
TOTAL	47	118	124	289

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF ANIMAL HUSBANDRY

Table 5

TABLE 5A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	23	28	43	94
UNITED STATES	10	3	7	20
GREAT BRITAIN	4	6	6	16
WEST GERMANY	5	3	8	16
FRANCE	5	.	2	7
NETHERLANDS	1	3	3	7
ITALY	.	2	1	3
SWEDEN	.	1	1	2
SWITZERLAND	2	.	.	2
AUSTRALIA	.	.	1	1
UNKNOWN	.	1	.	1
-----	---	---	---	---
TOTAL	50	47	72	169

TABLE 5B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
AUSTRALIA	.	1	10	11
GREAT BRITAIN	.	1	9	10
SOUTH AFRICA	.	2	8	10
SPAIN	.	.	9	9
UNITED STATES	.	1	8	9
BRAZIL	.	1	4	5
PORTUGAL	.	.	5	5
CANADA	.	.	4	4
JAPAN	.	.	4	4
DENMARK	.	.	2	2
FRANCE	.	.	2	2
WEST GERMANY	.	.	2	2
AUSTRIA	.	.	1	1
-----	---	---	---	---
TOTAL	0	6	68	74

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF AGRICULTURAL CHEMICALS

Table 6

TABLE 6A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
WEST GERMANY	494	219	96	809
UNITED STATES	284	199	105	588
SWITZERLAND	245	72	30	347
GREAT BRITAIN	126	73	36	235
ISRAEL	46	59	47	152
FRANCE	77	23	12	114
JAPAN	80	23	8	111
ITALY	9	15	5	29
HUNGARY	3	8	7	18
NETHERLANDS	7	3	.	10
AUSTRALIA	3	2	3	8
LUXEMBOURG	3	3	2	8
AUSTRIA	2	1	.	3
SOUTH AFRICA	1	1	1	3
CANADA	1	.	1	2
SWEDEN	2	.	.	2
BELGIUM	1	.	.	1
DENMARK	.	1	.	1
FINLAND	.	.	1	1
ROMANIA	1	.	.	1
UNKNOWN	.	.	1	1
TOTAL	1387	702	355	2444

TABLE 6B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN	2	4	7	13
AUSTRALIA	2	.	7	9
SOUTH AFRICA	.	1	8	9
UNITED STATES	2	3	4	9
CANADA	1	1	2	4
AUSTRIA	1	2	.	3
CZECHOSLOVAKIA	.	.	3	3
FRANCE	2	1	.	3
DENMARK	2	.	.	2
JAPAN	.	.	2	2
SPAIN	.	.	2	2
SWEDEN	2	.	.	2
SWITZERLAND	1	.	1	2
WEST GERMANY	.	.	2	2
ARGENTINA	.	1	.	1
CYPRUS	.	1	.	1
HUNGARY	.	.	1	1
ITALY	1	.	.	1
NETHERLANDS	.	1	.	1
PHILIPPINES	.	.	1	1
TOTAL	16	15	40	71

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF BIOCHEMISTRY 1 - APPARATUS

Table 7

TABLE 7A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	1	4	15	20
UNITED STATES	.	.	5	5
WEST GERMANY	.	2	3	5
FRANCE	.	.	2	2
GREAT BRITAIN	.	.	2	2
SWITZERLAND	.	.	2	2
AUSTRALIA	.	.	1	1
SOUTH AFRICA	.	.	1	1
-----	---	---	---	---
TOTAL	1	6	31	38

TABLE 7B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
AUSTRALIA	.	.	2	2
DENMARK	.	.	2	2
FRANCE	.	.	2	2
GREAT BRITAIN	.	.	2	2
JAPAN	.	.	2	2
UNITED STATES	.	.	1	1
WEST GERMANY	.	.	1	1
-----	---	---	---	---
TOTAL	0	0	12	12

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF BIOCHEMISTRY 2 - MICROORGANISMS

Table 8

TABLE BA

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES .		55	358	413
ISRAEL .		11	78	89
WEST GERMANY .		19	58	77
GREAT BRITAIN .		16	45	61
JAPAN .		3	31	34
SWITZERLAND .		5	13	18
AUSTRALIA .		.	16	16
FRANCE .		.	8	8
DENMARK .		.	7	7
ITALY .		1	5	6
CANADA .		.	3	3
NETHERLANDS .		.	3	3
FINLAND .		.	2	2
HUNGARY .		.	2	2
NEW ZEALAND .		1	1	2
SOUTH AFRICA .		.	1	1
SWEDEN .		.	1	1
-----	---	---	---	---
TOTAL	0	111	632	743

TABLE BB

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN .		3	19	22
WEST GERMANY .		4	5	9
FRANCE .		2	5	7
SOUTH AFRICA .		.	6	6
SWEDEN .		1	5	6
JAPAN .		.	5	5
UNITED STATES .		.	3	3
CANADA .		.	2	2
DENMARK .		2	.	2
FINLAND .		.	2	2
ITALY .		.	1	1
NETHERLANDS .		1	.	1
NORWAY .		.	1	1
-----	---	---	---	---
TOTAL	0	13	54	67

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF BIOCHEMISTRY 3 - PROCESSES

Table 9

TABLE 9A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	.	15	27	42
WEST GERMANY	.	4	16	20
GREAT BRITAIN	.	1	10	11
JAPAN	.	2	6	8
ISRAEL	.	3	4	7
SWITZERLAND	.	1	3	4
HUNGARY	.	1	2	3
ITALY	.	1	2	3
NETHERLANDS	.	.	3	3
DENMARK	.	1	1	2
FRANCE	.	.	2	2
AUSTRALIA	.	.	1	1
NEW ZEALAND	.	1	.	1
-----	-----	-----	-----	-----
TOTAL	0	30	77	107

TABLE 9B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
JAPAN	.	2	3	5
FRANCE	.	1	3	4
SOUTH AFRICA	.	.	2	2
AUSTRALIA	.	.	1	1
GREAT BRITAIN	.	.	1	1
UNITED STATES	.	1	.	1
WEST GERMANY	.	.	1	1
-----	-----	-----	-----	-----
TOTAL	0	4	11	15

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF BIOCHEMISTRY 4 - TESTING

Table 10

TABLE 10A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	.	10	22	32
ISRAEL	.	9	14	23
WEST GERMANY	.	4	16	20
GREAT BRITAIN	.	1	2	3
ITALY	.	1	2	3
FRANCE	.	.	1	1
SWITZERLAND	.	.	1	1
-----	---	---	---	---
TOTAL	0	25	58	83

TABLE 10B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN	.	2	3	5
FRANCE	.	1	3	4
JAPAN	.	1	3	4
UNITED STATES	.	2	2	4
SWEDEN	.	1	2	3
WEST GERMANY	.	2	1	3
AUSTRALIA	.	.	2	2
DENMARK	.	.	2	2
FINLAND	.	.	2	2
CANADA	.	.	1	1
SOUTH AFRICA	.	1	.	1
-----	---	---	---	---
TOTAL	0	10	21	31

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF FERTILIZERS

Table 11

TABLE 11A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
WEST GERMANY	10	11	8	29
ISRAEL	5	8	4	17
UNITED STATES	3	3	6	12
FRANCE	2	1	2	5
GREAT BRITAIN	2	2	1	5
SOUTH AFRICA	2	.	.	2
AUSTRALIA	.	1	.	1
JAPAN	1	.	.	1
NETHERLANDS	.	.	1	1
-----	---	---	---	---
TOTAL	25	26	22	73

TABLE 11B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
FRANCE	3	3	.	6
UNITED STATES	1	4	.	5
AUSTRIA	.	2	.	2
GREAT BRITAIN	.	2	.	2
SOUTH AFRICA	.	2	.	2
WEST GERMANY	2	.	.	2
AUSTRALIA	.	1	.	1
BRAZIL	.	.	1	1
JAPAN	.	.	1	1
NETHERLANDS	1	.	.	1
-----	---	---	---	---
TOTAL	7	14	2	23

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PHT - DAIRY

Table 12

TABLE 12A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	15	13	7	35
UNITED STATES	7	6	10	23
WEST GERMANY	3	2	3	8
FRANCE	5	1	.	6
GREAT BRITAIN	3	1	.	4
SOUTH AFRICA	1	1	.	2
SWEDEN	.	1	1	2
SWITZERLAND	2	.	.	2
ITALY	1	.	.	1
LUXEMBOURG	1	.	.	1
NORWAY	1	.	.	1
UNKNOWN	1	.	.	1
-----	---	---	---	---
TOTAL	40	25	21	86

TABLE 12B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
WEST GERMANY	1	3	.	4
AUSTRALIA	.	1	1	2
CANADA	.	.	2	2
FRANCE	.	1	1	2
NETHERLANDS	1	1	.	2
SOUTH AFRICA	.	1	1	2
UNITED STATES	.	.	2	2
GREAT BRITAIN	.	1	.	1
SWEDEN	1	.	.	1
SWITZERLAND	1	.	.	1
-----	---	---	---	---
TOTAL	4	8	7	19

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PHT - FRUIT

Table 13

TABLE 13A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	11	17	6	34
ISRAEL	4	4	9	17
ITALY	4	4	2	10
FRANCE	5	.	.	5
SPAIN	2	.	2	4
SOUTH AFRICA	2	.	.	2
SWITZERLAND	.	.	1	1
WEST GERMANY	1	.	.	1
-----	---	---	---	---
TOTAL	29	25	20	74

TABLE 13B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN	.	.	2	2
FRANCE	.	.	1	1
SPAIN	1	.	.	1
UNITED STATES	.	.	1	1
-----	---	---	---	---
TOTAL	1	0	4	5

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PHT - MILLING GRAIN

Table 14

TABLE 14A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	5	5	2	12
UNITED STATES	2	5	1	8
FRANCE	1	.	2	3
AUSTRIA	2	.	.	2
SWITZERLAND	1	1	.	2
WEST GERMANY	1	.	1	2
AUSTRALIA	.	.	1	1
CANADA	1	.	.	1
GREAT BRITAIN	1	.	.	1
NETHERLANDS	1	.	.	1
----- TOTAL	15	11	7	33

TABLE 14B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
WEST GERMANY	1	.	1	2
UNITED STATES	1	.	.	1
----- TOTAL	2	0	1	3

Table 15

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PHT - MEAT

TABLE 15A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	6	7	6	19
ISRAEL	6	5	7	18
GREAT BRITAIN	1	2	3	6
WEST GERMANY	4	.	1	5
CANADA	.	1	.	1
ITALY	.	.	1	1
NETHERLANDS	1	.	.	1
-----	---	---	---	---
TOTAL	18	15	18	51

TABLE 15B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
DENMARK	.	.	2	2
-----	---	---	---	---
TOTAL	.	.	2	2

Table 16

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF PHY - GENERAL

TABLE 16A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
UNITED STATES	118	72	48	238
ISRAEL	58	43	49	150
GREAT BRITAIN	35	18	18	71
WEST GERMANY	31	21	19	71
SWITZERLAND	26	6	4	36
FRANCE	13	4	8	25
ITALY	7	4	4	15
HUNGARY	5	2	3	10
JAPAN	1	2	4	7
AUSTRALIA	2	2	2	6
NETHERLANDS	4	1	1	6
MEXICO	4	.	.	4
SOUTH AFRICA	4	.	.	4
UNKNOWN	3	.	.	3
AUSTRIA	1	1	.	2
DENMARK	1	.	1	2
NORWAY	2	.	.	2
SWEDEN	.	.	2	2
ARGENTINA	.	.	1	1
BELGIUM	.	.	1	1
NEW ZEALAND	.	1	.	1
POLAND	1	.	.	1
SPAIN	.	.	1	1
----- TOTAL	316	177	166	659

TABLE 16B

GRANTING COUNTRY	1973-77	1978-82	1983-87	TOTAL
GREAT BRITAIN	1	4	6	11
UNITED STATES	5	4	1	10
AUSTRALIA	2	3	4	9
SOUTH AFRICA	1	4	3	8
WEST GERMANY	3	4	1	8
DENMARK	2	1	3	6
FRANCE	5	.	1	6
JAPAN	3	1	2	6
NETHERLANDS	1	2	2	5
CANADA	1	2	1	4
SPAIN	.	.	3	3
SWEDEN	1	1	1	3
AUSTRIA	2	.	.	2
BELGIUM	.	1	1	2
SWITZERLAND	.	1	1	2
BRAZIL	.	.	1	1
FINLAND	.	.	1	1
KOREA	.	.	1	1
NEW ZEALAND	.	.	1	1
PHILIPPINES	.	.	1	1
UNKNOWN	.	1	.	1

PATENTS GRANTED IN ISRAEL TO NATIONALS OF ALL COUNTRIES (TABLE A)
AND PATENTS GRANTED ABROAD TO ISRAELI NATIONALS (TABLE B)
FOR 1973-77, 1978-82 AND 1983-87
IN THE FIELD OF SUGAR PROCESSING

Table 17

TABLE 17A

PRIORITY COUNTRY	1973-77	1978-82	1983-87	TOTAL
ISRAEL	2	1	3	6
ITALY	3	1	.	4
UNITED STATES	.	1	2	3
WEST GERMANY	.	2	.	2
AUSTRIA	.	1	.	1
BELGIUM	1	.	.	1
JAPAN	1	.	.	1
----- TOTAL	7	6	5	18

TABLE 17B

(NO ENTRIES)

Table 18

PATENTING IN ISRAEL BY NATIONALS ("I" VARIABLES),
PATENTING IN ISRAEL BY FOREIGNERS ("F" VARIABLES),
AND PATENTING (ABROAD) BY ISRAELI NATIONALS ("A" VARIABLES)
FOR 17 AGRICULTURAL TECHNOLOGY FIELDS AND 3 TIME PERIODS

*All Israeli
patents - at home
and abroad*

FIELD	17377	17882	18387	F7377	F7882	F8387	A7377	A7882	A8387
PLANTING	10	14	22	18	8	14	16	17	27
SOIL WORKING	12	13	17	14	4	2	23	16	20
HARVESTING	6	22	47	9	7	21	11	23	56
HORTICULTURE	60	78	82	76	81	62	111	197	206
ANIMAL HUSBANDRY	23	28	43	27	19	29	23	35	111
AGR. CHEMICALS	46	59	47	1341	643	308	75	74	52
BIOCHEM 1 - APPARATUS	1	4	15	.	2	16	.	4	27
BIOCHEM 2 - MICROORGES	.	11	78	.	100	554	1	24	130
BIOCHEM 3 - PROCESSES	.	3	4	.	27	73	.	7	15
BIOCHEM 4 - TESTING	.	9	14	.	16	44	.	19	32
FERTILIZERS	5	8	4	20	18	18	12	22	6
PNT DAIRY	15	13	7	25	12	14	20	21	14
PNT FRUIT	4	4	9	25	21	11	5	4	12
PNT MILLING GRAIN	5	5	2	10	6	5	6	5	7
PNT MEAT	6	5	7	12	10	11	6	5	9
PNT GENERAL	58	43	49	258	134	117	98	72	96
SUGAR PROCESSING	2	1	3	5	5	2	2	1	3

Concomitantly, patenting abroad by Israel, though still small in absolute numbers, has also increased, with the chief target again being Great Britain and the United States.

B. Horticulture and Animal Husbandry

Tables 4 and 5 report patent trends for horticultural and animal husbandry inventions. These relatively "low-tech" agricultural production fields nevertheless show a great deal of activity during the period under investigation. Though higher than for agricultural machinery, the transferability of these technologies is still rather low, and once again Israeli inventors are the leading recipients of Israeli patents, accounting for about half of all horticulture patents and roughly 56% of all animal husbandry patents.

The most striking feature of these data is the rapid internationalization of Israeli technology over the period. The number of patents granted abroad to Israeli inventors increased by over 160% among horticultural inventions, even though only 37% more patents were granted domestically to Israeli inventors. In animal husbandry, the change is even more acute: during 1973-77, not a single patent was granted abroad in any of the countries in the INPADOC data set, while from 1983-87 68 patents were granted. The principle targets of the surge in Israeli technology exports were Australia, Spain, Italy and South Africa.

At the same time, patenting by foreigners in Israel remained flat (animal husbandry) or declined (horticulture) during this period. Together with the data on patenting abroad, these figures indicate that Israel has become much less dependent on foreign technology in these areas and has, in fact, developed the ability to export what it has learned to countries with similar geoclimatic features.

C. Chemical Inventions

Tables 6-11 report data for six technologies based in chemical R&D, two traditional fields (agricultural chemicals, such as herbicides, pesticides and veterinary medicines, and fertilizers), and four recently developed biochemical technologies: apparatus, microorganisms, processes and testing methods.

Among the traditional technologies, the very important agricultural chemicals field shows a dramatic decrease in patenting from 1973-77 to 1983-87, falling from 1387 patents to 355. Israeli patents accounted for only about 6% of the total granted over the entire period. Among the four largest foreign recipients of patents, patent grants to U.S. inventors fell to one-third their 1973-77 level, for the U.K. the figure is one-fourth; for Germany, one-fifth, and for Switzerland, one-eighth. Patents granted to Israeli inventors remained flat.

These figures are cause for serious concern. We are currently unaware of any administrative or legal decision that would form the basis for this trend, but it runs considerably at variance with patterns in the rest of the world. Any weakening of patent protection, even in an area of obvious foreign dependence like this one, ultimately weakens the incentive and technology transfer mechanisms that spur investment in R&D; consequently, the long-run cost will be reductions in productivity growth in the agricultural sector, especially in those areas with a strong dependence on agricultural chemicals. It appears that the domestic Israeli capacity for agricultural chemical invention has been expanding, because the number of patents granted to Israeli inventors abroad, though still small, has increased markedly over the period. Of course, a policy that seeks to stimulate the domestic capacity to produce patentable research is a worthwhile goal, but this can be done directly without

reducing the availability of protection to foreigners. This matter deserves further investigation.

Patenting in fertilizers, which is a relatively old and stagnant technology, remained flat in Israel, with West Germany being the principal exporter of technology to Israel. After some expansion of patenting abroad by Israeli inventors in the mid- to late-1970s, only 2 patents were granted abroad during the last period.

We turn now to the four biotechnology fields. Because these fields were only added to the IPC coding system in 1980, it is more difficult to draw inferences about their specific trends, given the time periods chosen. Nevertheless, the overall pattern is clear. Patenting in all fields, especially microorganisms, has been expanding rapidly since 1980. Although the field is dominated in Israel by the United States, which accounted for half of all patents granted in Israel, domestic Israeli patent production is as great as that of any other foreign country, about 14% of the total. Israeli patenting abroad has also been on the rise. As will become clear in the next section of the paper, Israel has far and away the greatest export capacity in biotechnology inventions of any of the countries commonly labelled "developing or newly industrializing." This can only be taken as an encouraging sign, given the tremendous potential for growth in productivity due to biotechnology that is predicted to occur.

While our emphasis naturally is on the production of inventions in Israel, it is worth noting that Israel appears to be an attractive market for a large number of developed countries that also generate biotechnology. This indicates that institutional circumstances, among others, facilitate a high level of transferability of biotechnology, both to and from Israel. One should not infer, however, that the broad pattern seen here applies to

agriculturally-related biotechnology. For these inventions, the degree of transferability is much less. We also do not have precise enough measurements of the agricultural component of biotechnology patenting to see if Israel is strong or weak, relative to its overall generating capacity, in this area.

D. Post-Harvest Technology

Six post-harvest technology (PHT) fields constitute the final group of our analysis, covering dairy, fruit, meat, and grain processing, as well as general technology that is not specific to a particular food group, and sugar processing that may or may not be food-related. The United States (35%) and Israel (26%) together account for over half of all patents granted in Israel in these fields; only West Germany counts for as much as 10%. Overall patenting in most fields is down, however: total patenting in all fields fell from 425 patents in 1973-77 to 237 in 1983-87, a drop of nearly half. As with agricultural chemicals, patenting by Israeli inventors has not suffered the sharp decline that inventions originating abroad exhibited.

Post-harvest technology is usually easily transferable, as can be seen by the wide variety of countries that have obtain PHT patents in Israel. Israel's export capacity in post-harvest technology appears to be rather limited, however, relative to its domestic generating capacity, in each of the fields studied.

Table 18 reports a summary of Israeli invention in Israel ("I" variables), other countries's invention in Israel ("F") and invention ^{in Israel and} abroad by Israeli inventors ("A"). The broadest trend to be observed is that patents granted to foreign inventors have declined in all fields except the rapidly growing biotechnology fields. Israeli invention in Israel in all fields has increased, except in fertilizers and in three of the post-harvest fields. more impressively, Israeli invention abroad has increased in all of the fields as

well. This is particularly impressive in the biochemical fields, where Israel is one of the few countries active in invention in a number of the fields.

In evaluation, we can note the following main points. First, although Israel should still be considered a net importer of agricultural technology, it has developed a substantial research base and supplies a significant share of its own technology needs. In many fields this share appears to be increasing. The improvement in Israel's technology generating capacity relative to the rest of the world can be seen in its increased ability to "export", especially in the areas of biotechnology, where rapid both at home and abroad is easily observable. The fact that Israel serves as an attractive market for foreign inventors should be taken as a good sign, given its own relatively strong research base, because this indicates the potential for significant adaptive improvements of foreign inventions being protected in Israel.

Weighing against these encouraging signs are the sharp drops in traditional agricultural chemicals and in post-harvest technology. As we noted earlier, the developed world stands in contrast to the developing world in that it encourages patenting on food- and agriculture-related inventions. From our perspective, it would be a policy mistake for Israel to undertake any systematic weakening of its patent system as it pertains to agricultural invention. There are alternatives to this type of technological "protectionism," such as the creation of a petty patent system to stimulate domestic invention, that have less deleterious effects on the country's long-term capacity to produce and appropriate new technologies.

III. Comparisons of Agricultural Invention in Other Countries

The data that bear most directly on the generation and use of biotechnology in the developing countries are contained in Tables 19, 20, and 21. These tables present patent counts in the same three technology fields, biochemistry per se, agricultural chemicals and horticulture. Table 19 refers to biotechnology, while Tables 20 and 21 present comparison data for agricultural chemical and horticultural inventions, respectively. Each table shows the patenting in a set of developing countries by all other countries, including developed countries, and each table shows patenting by developing countries in all other countries.

In the case of biotechnology patenting in the developing countries, we further disaggregated the data to show what types of patenting is taking place, and to discern any gross trends. The biotechnology field comprises four subfields; biochemical apparatus (International Patent Classification C12M), microorganisms (C12N), processes (C12P), and testing (C12Q); and two time periods (1980-83 and 1984-87).

Tables 19, 20 and 21 show that the invention patterns for developing countries -- even advanced developing countries such as Brazil and South Korea -- is mostly a one-way pattern. Even when there is evidently some domestic capacity for generating technology, for the most part, developing countries do not sell biotechnology-related inventions abroad. That is, developing countries do not find it in their interest to obtain patents abroad either in other developing countries or in developed countries. This is true primarily because their inventions tend to be local adaptations to inventions made in the developed countries.

TABLE 19
PATENT COUNTS IN BIOTECHNOLOGY
BY PRIORITY COUNTRY AND GRANTING COUNTRY
1980-88

GRANTING COUNTRY																																				
PRIORITY COUNTRY	DEVELOPING COUNTRIES															DEVELOPED COUNTRIES															TOTAL	EXPORT				
	A	R	E	H	I	K	K	M	M	P	P	E	Z	U	C	J	D	G	F	I	N	C	A	A	N	S	N	D	F	Z			E	W		
	R	R	G	K	N	L	E	R	W	X	N	H	T	S	M	A	P	E	B	R	T	L	H	T	U	Z	E	O	K	I			A	P	O	
ARGENTINA	9															2	1		1						2									15	0.67	
BRAZIL		114													3		1	1	2	2	2	2				3	1			2	2	3	140	0.23		
CHILE																																		0		
EGYPT			1																															1	0.00	
HONG KONG																																		0		
INDIA																																		0		
ISRAEL					145										5		10	3	20	15	34	17	1	2	1	6	1	9	1	8	4	10	28	1	321	1.21
KENYA																																		0		
KOREA							215									3	7	2														1	3	231	0.07	
MALAWI																																		0		
MALAYSIA																																		0		
MEXICO										35						1																		36	0.03	
MONGOLIA											4																							4	0.00	
PHILIPPINES																	1																	2		
PORTUGAL													15					1																16	0.07	
SINGAPORE																																		0		
SPAIN	3	2		1					2					307		4	1	3	2	2	5	1	1		1				1	1	4		345	0.12		
TAIWAN																																		0		
VENEZUELA																																		0		
ZAMBIA																																		0		
ZIMBABWE																																		0		
UNITED STATES	48	126	3	27		487	11	51		25		10	356	801																				1945		
WEST GERMANY	11	37	1	5		122				3			112	271	1																			563		
GREAT BRITAIN	5	50		4		77	4	7		3		2	101	209	1																			463		
JAPAN	11	31		1	2	42		35		15		5	30	289																				461		
FRANCE	4	20		1		13				2			44	98																				182		
SWITZERLAND	2	9		1		25		3		3		1	14	52																				110		
ITALY	5	6				12			1	1			10	35																				70		
DENMARK		5				9							6	45																				65		
AUSTRALIA		7				18		1		1		2	6	19																				54		
NETHERLANDS		3				6							11	14																				34		
SWEDEN		8				1				2			3	6																				20		
HUNGARY						5							2	10																				17		
SOUTH AFRICA		3				2							2	4	1																			12		
AUSTRIA		2								1			1	6																					10	
NEW ZEALAND		1				3				1				4																					9	
POLAND		1											2	6																					9	
SOVIET UNION		2												4																					6	
CANADA		2				3																													5	
EAST GERMANY							1							4																					5	
FINLAND		2				2																													4	
TRINIDAD & TOB		1																																	1	
TOTAL	98	432	5	39	3	972	15	313	1	94	4	20	715	2192	1	2	21	5	34	22	39	24	1	3	1	1	12	1	10	1	8	5	13	36	7	5156

TABLE 21
PATENT COUNTS IN HORTICULTURE
BY PRIORITY COUNTRY AND GRANTING COUNTRY
1980-88

GRANTING COUNTRY

	DEVELOPING COUNTRIES												DEVELOPED COUNTRIES																							
PRIORITY COUNTRY	A R	B R	E S	H K	I N	K L	K R	M W	M X	P H	P T	E Z	U S	J A	D P	G B	F R	I N	C A	A N	S D	N F	Z E	W A	TOTAL	EXPORT										
ARGENTINA	43				1							3		1	1							1	1		51	0.15										
BRAZIL	2	186			1			1				3											1		174	0.04										
CHILE																									0											
EGYPT			2																						2	0.00										
HONG KONG																									0											
INDIA				12						1															13	0.09										
ISRAEL	4	6			143			3		6	37		14	3	7	10	16	18	18	6	5	40	1	3	5	11	25	381	1.66							
KENYA							436																		0											
KOREA														1								3			440	0.01										
MALAWI																									0											
MALAYSIA																									0											
MEXICO	1	1			3			9		2	3			1		1	1	1			2			1	1	27	2.00									
MONGOLIA									1																1	1	1	0.00								
PHILIPPINES										7															7	0.00										
PORTUGAL											20														20	0.00										
SINGAPORE																									0											
SPAIN	1	1	1		1						1293		3	3	3	4	10	1	3			2		1	4	1333	0.63									
TAIWAN																									0											
VENEZUELA																									0											
ZAMBIA																									0											
ZIMBAWE																								1	1											
UNITED STATES	9	32	2	3	4	38	2	3	9	6	21	72													202											
FRANCE	3	5	2		1	5			2		23	63													104											
GREAT BRITAIN	2	3	1	2	1	11				2	10	14													47											
WEST GERMANY		7		1	1	9					6	20													44											
ITALY	1	5				4		4			7	8													29											
JAPAN	1	2	1	1	2	2		4	5	3															21											
SWEDEN	2	2		1		5			2			8													20											
SWITZERLAND		4	1			6			1		1	4													17											
AUSTRALIA		4				4			2																10											
DENMARK		2									5	2													9											
HUNGARY	1	1		1					1		1	4													9											
NETHERLANDS											1	7													8											
NEW ZEALAND					1	3					1	2													7											
AUSTRIA					1	5																			6											
FINLAND		1			2							2													5											
SOUTH AFRICA						1						1	1												3											
SOVIET UNION											2														2											
IRELAND						1																			1											
NORWAY						1																			1											
TOTAL	70	262	10	9	25	244	2	447	0	35	1	19	106	1545	1	3	17	3	13	14	21	29	20	9	0	5	45	1	0	3	8	0	15	31	0	3015

TABLE 20
PATENT COUNTS IN AGRICULTURAL CHEMICALS
BY PRIORITY COUNTRY AND GRANTING COUNTRY
1980-88

PRIORITY COUNTRY	GRANTING COUNTRY																			TOTAL	EXPORT															
	DEVELOPING COUNTRIES														DEVELOPED COUNTRIES																					
	A R	B R	E G	H K	I N	I L	K E	K R	M W	M X	M N	P H	P T	E S	Z M	Z W	U S	C A	D E			G F	I N	C A	A N	S D	N F	Z I	E A	F O						
ARGENTINA	73	1														1	1												76	0.04						
BRAZIL		82															2	2					1		2	2	2	1	1	1	97	0.19				
CHILE																														0						
EGYPT			22																											22	0.00					
HONG KONG																														0						
INDIA					60																1									0						
ISRAEL	1					79							1		2		6	3	3	3	11	2	2	1	1	9			10	10	1	145	0.84			
KENYA																														0						
KOREA								132									1													133	0.01					
MALAWI									1																					1	0.00					
MALAYSIA																														0						
MEXICO										32																				0						
MONGOLIA																														32	0.00					
PHILIPPINES													55																	0						
PORTUGAL													24																	55	0.00					
SINGAPORE																														24	0.00					
SPAIN	1													1	154						1	1								0						
TAIWAN																														158	0.03					
VENEZUELA																														0						
ZAMBIA															7															0						
ZIMBABWE																5														7	0.00					
																														5	0.00					
UNITED STATES	250	278	96	11	57	186	10	32	12	41		164	111	138	9	34														1429						
WEST GERMANY	187	200	135	2	15	178	10		5	10		130	134	133	1	27														1167						
GREAT BRITAIN	52	79	27	9	16	65	15	2	9	10		53	53	63	13	41														507						
JAPAN	50	69	34	4	15	18		13		4		91	7	23	1	2														331						
SWITZERLAND	32	54	29		2	44	5			2		37	10	21		19														255						
FRANCE	34	35	16	1	1	15	2			2		24	24	47		4														205						
ITALY	10	23	15		7	15	4	1		2		4	7	14																102						
HUNGARY	6	23	3		1	11				2		2	21	26																95						
LUXEMBOURG	8	4	1		2	4	1					2	5	8																35						
NETHERLANDS	7	2	6	1		2		1				2		6		5														32						
AUSTRALIA	3	7	1			4	1			1		2	1	6																26						
SOUTH AFRICA		5				2			4			2	1		3	8														25						
SWEDEN	3	1								1				3																8						
CANADA	1	1				1						1		2																6						
POLAND		1			1									1																3						
AUSTRIA			1																											1						
USA		1																												1						
DENMARK													1																	1						
FINLAND						1																								1						
NEW ZEALAND	1																													1						
TOTAL	719	866	386	28	177	625	48	181	31	105	2	570	400	647	34	146	10	3	5	3	12	3	1	2	1	1	14	0	0	2	2	2	11	11	2	5051

Notes to Tables 19, 20, and 21

1. Because of slightly different data collection techniques, the data for patents by developed countries in developing countries cover the period 1980-87.
2. The standardized codes for the country names that are used by INPADOC, the International Patent Documentation Center, follow: they are given in capital letters when their abbreviation forms part of the English name, in parentheses otherwise. Argentina, Brazil, Egypt, Hong Kong, India, Israel, Kenya, Korea, Malawi, Mexico, Mongolia, Philippines, Portugal, Spain (ES), Zambia, Zimbabwe, United States, Canada, Japan, West Germany (DE), Great Britain, France, Italy, Netherlands, Switzerland (CH), Austria, Australia, New Zealand, Sweden, Norway, Denmark, Finland, South Africa (ZA). The designations EP and WO stand for the European Patent Office and "World" patent applications, respectively. The European Patent Office receives applications and grants patents which then have the same legal standing in each designated European member country as a national patent. They are not separate patents themselves. "World" patent applications are filed under the Patent Cooperation Treaty, which allows a standardized application to be filed in all designated member countries. The applications themselves are examined by the national offices according to the usual standards.
3. The column headed "Export" is a the value of a variable defined as the ratio total patents obtained abroad to total patents obtained at home by citizens of the country in question.

On the other hand, it is clear that several of the advanced developing countries (and Israel) are large buyers of technology, as reflected in the willingness of developed country sellers to obtain protection in these countries. The purchase of technology by developing countries is somewhat broader in the more traditional agricultural chemical fields than in the newer biotechnology fields. Argentina, Brazil, Egypt, Korea, Mexico, Portugal and Spain are large buyers of biotechnology. The Philippines and India buy significant amounts of agricultural chemical technology.

For agricultural chemicals, Argentina, Brazil, Mexico, Korea, the Philippines and India, as well as Israel, have significant local adaptive invention capacity. For biotechnology, only Brazil and Korea (and Israel) have developed this capacity.

The summary tables mask several important features of the underlying data, which was disaggregated into two time periods. The most obvious of these is that biotechnology-related inventions are being produced at an accelerating rate. Overall, biotechnology patenting increased from 20 patents in 1980-83 to 1247 in 1984-87, with the largest category, patents related to microorganisms, more than doubling from 331 to 793. By contrast, patenting in agricultural chemicals and horticulture decline during this period.

There are sharp intercountry differences in this pattern, however. Argentina, which has long been the target of complaints from the developed world about its lax patent enforcement, saw precipitous declines in all six fields studied. As we noted earlier, Israel, on the other hand, exhibited significant gains in biotechnology, even while agricultural chemicals and horticulture declined. Spain shows a sharp increase in patenting activity both by foreign and domestic firms. In Korea, evidence indicates that the patenting by domestic firms of biotechnology-related invention has slowed down, even

while Japanese and American firms have begun to penetrate the market (and to exhibit confidence in the Korean patent system, which has been the most visible target of U.S. allegations of piracy).

IV. Comparisons with BARD Survey Data

Israel is a major producer of agricultural inventions. The data summarized in this paper are much more comprehensive than the data analyzed in the report, The R&D Process in Research Centres and Industry Related to Agriculture in Israel (published by the Interdisciplinary Center for Technological Analysis and Forecasting, Tel-Aviv University), which was based on the BARD-sponsored survey.

The BARD survey data on patents are summarized in Tables 22, 23 and 24. These data provide additional insight for Israeli invention by showing the distribution of inventions by the institution that conducted the research. Table 22 reports the distribution of the 176 patents analyzed in the BARD survey. These are distributed in roughly the same proportions as are those based on the INPADOC data. The 966 patents in the INPADOC survey were granted over a longer period of time and the field definitions were broader.

Table 23 shows that the Vulcani Institute in Israel obtained 37 percent of Israeli patents (higher in the most recent period. While this proportion would probably not hold for the larger sample, it is indicative of the important role that the Vulcani Institute is playing in agricultural invention.

Table 24 shows that not only are research centers important in Israel's invention, but that independent inventors are also of greater importance in some fields than is the case in other countries. In the U.S. about 30 percent of agricultural invention is undertaken by independent inventors.

Table 22

. Patents registred in Israel in
selected agricultural related industries
(Number of Patents)

	Period #1	Period #2	Period #3	Total
Irrigation System	6	11	7	24
Irrigation devices (Pumps-Valves...)	1	4	1	6
Agricultural machinery electronic Apparatus	10	16	17	43
Machinery Metal Products	22	25	37	84
Chemical-Foodstuff Others	9	3	7	19
Total	48	59	69	176

See Annex 1

Table 23

Patents registered by ^oVulcani Institute of Israel
by periods/major sectors (number of patents)

	Period *1	Period *2	Period *3	Total
Machinery-Electric Apparatus	2	3	10	15
Machinery Metal Products	11	8	21	40
Irrigation systems and devices	-	-	1	1
Chemicals products Foodstuff	2	1	7	10
Total	15	12	39	66

1 Period 1 : 1973-1976

2 Period 2 : 1977-1980

3 Period 3 : 1981-1985

Table 24

Inventors in Agricultural-related Industries
(Number of Inventors)

	Agricultural machinery metal products Electronics	Irrigation systems and devices	Chemicals- foodstuff Others	Total
Firm	19	11	2	32
Research Center	41	1	10	52
Independent inventor	57	21	6	84
Total	117	33	18	168

Table 25 reports further data on the level of education of Israeli inventors, showing that most inventors have a high level of technical training. Indeed, almost half have graduate-level training. Table 26 confirms that many inventors are obtaining more than one patent and that they are obtaining patents abroad.

Thus, we have a relatively good picture of agricultural invention in Israel. The general picture indicates that Israel is an international leader in many fields of invention.

Table 25

Inventors' Level of Education and Main Specialization

Specialization \ Education level	PHD/ Prof.	M.A	Engineer	B.A.	Others	Total
Agriculture	1	1		3		6
Diagnostics-Chemical Plastics-Pharmceutics Veterinary	4	1		2		7
Electronics Computers Mathematics/Physics	2	1		2	1	6
Machinery - automation	4	1	3	4	6	18
Others					1	1
Total	11	4	3	11	9	38

Table 26

Inventors - Number of Patents registered
(Number of Patents)

Number of Patents	In Israel	Abroad
1	11	3
2-5	18	12
+5	9	7
	38	22

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