PROGRAM OF DEVELOPMENT STUDIES
121 Sewall Hall

WILLIAM MARSH RICE UNIVERSITY
Houston, Texas 77001

Paper No. 56

Managerial Discretion and the Choice of Technology by Multinational Firms in Brazil

by

Samuel A. Morley

and

Gordon W. Smith

Fall, 1974

The authors are respectively Associate Professor of Economics, University of Wisconsin, and Associate Professor of Economics at Rice University. The research reported in this paper was financed by the National Science Foundation under grant number GS-34581. Program Discussion Ppaers are preliminary materials circulated to stimulate discussion and critical comment. References in publications to Discussion Papers should be cleared with the authors to protect the tentative character of these papers.

1. Introduction

One of the most serious charges leveled against multinationals operating in LDC's is that they employ capital - and skill-intensive technologies grossly inappropriate for labor abundant economies --- with the inevitable consequences for unemployment and income distribution.[1] Support for this proposition has usually been more polemical and ideological than scientific in nature. But there is a growing body of empirical evidence which does suggest that the response of multinationals to low labor costs has not been very great. For example, Wayne Yeoman found that most U.S. multinationals he examined (thirteen) transferred their production processes intact to the poorer countries.[2] In Grant Reuber's sample of seventy-six multinationals, only nineteen claimed to have adapted their production technologies in any way to local conditions in LDC's.[3] Elesewhere in a study of thirty-five foreign firms in Brazil, we concluded that they had not changed production methods much to employ cheap Brazilian labor, although "scaling down" modifications for the smaller Brazilian market were undertaken.[4]

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[1]See, for example, Osvaldo Sunkel, "The Pattern of Latin American Dependence," in Victor L. Urquidi and Rosemary Thorp, Latin America in the International Economy (New York: 1973), pp. 19-23; Theotonio dos Santos, "The Structure of Dependence," American Economic Review, May, 1970, pp. 234-235; Winter 1973-74, pp. 78-85, 100-101.

[2]Wayne A. Yeoman, Selection of Production Processes for the Manufacturing Subsidiaries of U.S. Based Multinational Corporations, D.B.A. thesis, Harvard Business School (unpublished, 1968).

[3]Grant L. Reuber, et. al., Private Foreign Investment in Development (Oxford: 1973). In another question, 50 of 77 firms claimed they did not alter production techniques and 55 of 77 used the same production equipment.

[4]Samuel A. Morley and Gordon W. Smith, "The Choice of Technology: Multinational Firms in Brazil," Rice University Program of Development Studies Discussion Paper (mimeo, 1974).

The explanation of such minor adjustments is the critical element for policy. Of course, the range of engineering efficient technologies may be quite limited.[1] But there is another possibility. best viewed as an outcome of satisficing and/or managerial discretionary behavior as it appears in the "Carnegie models" of the firm.[2] Simply put, multinationals may not employ less familiar, labor-intensive methods, because market pressures do not force them to in order to meet profit targets and other goals. This view is at least suggested by Wayne Yeoman in the study mentioned above. Louis T. Wells argues managerial discretion more directly, without calling it that. When monopoloid power permitted, excessively capital-intensive techniques were chosen by his sample of firms in Indonesia (both domestic and foreign), basically, he maintains, to satisfy "engineering man's" desire for mechanical efficiency rather than economic man's drive for profits.[3]

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[1]See, for example, Richard S. Eckaus, "The Factor Proportions Problem in Underdeveloped Areas," American Economic Review, September, 1955, pp. 539-565; Christopher Clague, "Capital-Labor Substitution in Manufacturing in Underdeveloped Countries," Econometrica, July, 1969, pp. 528-537; Gerard K. Boon, Economic Choice of Human and Physical factors in Production (Amsterdam: 1964). Gustav Ranis has strongly disagreed with this position. Gustav Ranis, "Industrial Sector Labor Absorption," Economic Development and Cultural Change, April, 1973, pp. 387-408.

[2]See, for example, James G. March and Herbert A. Simon, Organizations (New York: 1958); Richard M. Cyert and James G. March, Behavioral Theory of the Firm (Englewood Cliffs, N. J.: 1963); and Oliver E. Williamson, The Economics of Discretionary Behavior: The Managerial Objectives in a Theory of the Firm (Chicago: 1967). "X-Inefficiency" is also relevant in this context. See Harvey Leibenstein, "Allocative Efficiency versus X-Efficiency," American Economic Review, June, 1966.

[3]Louis T. Wells, Jr., "Economic Man and Engineering Man: Choice of Technology in a Low-Wage Country," Public Policy, Summer, 1973, pp. 319-342.

In this paper, we formulate an explicit satisficing/managerial discretion model in which search costs, accumulated experience and a permissive environment play the key roles. The model is then tested, using Brazilian four and five digit manufacturing establishment data for 1969. Brazil is exellent for this purpose, since there is a very large foreign presence in its manufacturing sector[1] and its labor costs per worker remain one-fifth their U.S. levels despite Brazil's recent "economic miracle."[2]

Our tests yield considerable, if not overwhelming, support for satisficing managerial discretion as a partial explanation of multinationals' meager adaptation to low wages. Some policy implications of our findings are discussed in a final section. Before turning to all of this, however, it will be useful to summarize some results from interviews we conducted regarding technological choice.

2. The Perception of Technological Alternatives: Evidence from Questionnaires

Thirty-five foreign firms of several nationalities were interviewed personally by the authors in Sao Paulo and Rio de Janeiro. The questionnaire took between one and two hours to complete, while answers were supplied either by the production methods planner or by the vice-president in charge of production.

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[1]Special tabulations made for us by IBGE indicate that about 40% of total manufacturing value added in 1969 originated in firms controlled by foreign capital. By 1973, the figure would have been higher.

[2]This was the figure given by almost all the American firms we interviewed in Brazil.

When possible, plant vitis were also arranged. (A list of firms interviewed appears in Appendix 1)

We did not attempt a "representative" sampling of foreign operations in Brazil. Rather, we tried to choose lines produced by firms of several different nationalities in non-process industries. Hence, the automakers, the television-radio assemblers, the tele-communications field, diesel engines, bearings and tires were all included. We also wanted to interview the largest foreign firms operating in metal-working activities, which meant again the automakers and also auto parts, and some machinery firms.

The technological portion of the interviews centered on the following questions:

> "1. Rank the following factors in terms of their importance in your firm's choice of production methods (processes, machines, etc.): quality of product; labor costs; shortage of skilled labor; import licenses; cost and availability of financing; size of market; government incentives; others. Could you please give a specific example of how each of the three most important factors influenced the production methods chosen.
>
> 2. In the design of the plant, were the practices of similar firms elsewhere investigated? Where? In what respect?
>
> 3. Suppose machinery and equipment costs in Brazil (including imports) had been 100% higher in relation to labor costs/worker. How would this have changed the types and quantity of machines and the amount of labor employed, assuming no change in production levels?
>
> 4. Suppose production in Brazil were as large as an optimal plant in your home country. Would you then use the same types and quantity of machines as in your home country? The same quantity of labor? Explain."

With remarkable regularity, scale emerged as the overwhelming determinant of machine choice and labor use. Low labor costs in Brazil and/or the prospect of much higher machine costs were seen as having a small effect on factor pro-

portions in the great majority of cases. Multinationals use more, sometimes three or four times more, labor per unit of output in Brazil than in their home country, but they say this is primarily a result of their smaller scale operations in Brazil.

Table I presents the results of the rankings (question 1 above). Quality of product and market size are nearly tied for first place, while labor costs rank a distant third. Ironically labor costs were ranked as often as they

TABLE I

Frequency the Following Reasons for Technology Choice Were Ranked as Indicated[a]

RANK	1	2	3	Below 3
Quality of Product	17	7	3	
Size of Market	14	14	2	
Labor Costs	1	8	9	
Shortage of Skilled Labor	1	1	3	
Cost of Finance	0	2	3	
Government Incentives	0	0	3	
Import Licenses	0	0	1	

[a]Not all firms indicated all three first choices.

were only because several interviewees believed that a reduction in labor use would be a prime way to lower costs.

Another indication of the importance attributed to scale is the answer to the fourth question. If current scale in Brazil were as large as in the home

country, four of the interviewees said that machines and labor would be identical in both countries (see Table II). Most often, however, firms saw certain very limited areas where differences would still persist because of cheaper labor. These sometimes involved sophisticated quality control equipment or superautomated machining operations which are worthwhile in the home country, but would not be in Brazil. Only six firms interviewed claimed that significant differences would remain between the home operation and the Brazilian subsidiary at the same scale. Perhaps surprisingly three of these were automobile companies.

TABLE II

How Machines and Labor Used in Brazil Would Differ from:

	Home Country, if Scale Were as Large in Brazil	Current Brazilian Subsidiary, if Machine Prices Were Doubled
No Difference[a]	6	4
Slight Differences[a]	22	22
Moderate Differences[a] to Substantial Differences[a]	6	5
No Answer	0	3

[a] The answers were generally multidimensional except in the case of "no difference." The authors classified the other responses into these categories, based on their (partly subjective) views of their significance.

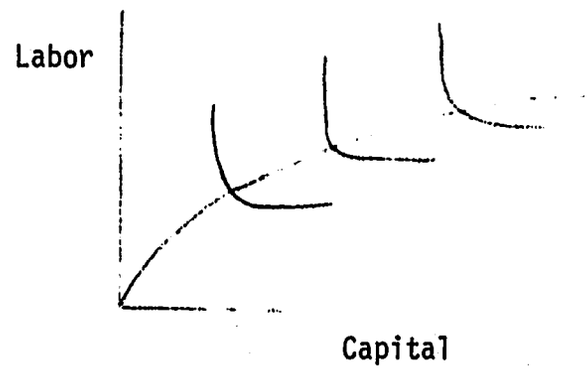
Another way of approaching this issue is through question 3 above (see Table II). Four of the thirty-one firms responding thought that a doubling of machine prices would bring no difference in machine and labor use. Most

often, slight differences were projected. But in a few cases, where automatic, higher volume equipment had recently been installed or was in the planning stage, higher machine costs would have made the moves uneconomical. A television assembler would not have gone to automatic plating. A truck maker would not have installed two new transfer lines. A tractor manufacturer would not buy an automatic-loading grinder. For some companies, the magnitude of the adjustments was low because they were already using simple, labor-intensive, universal machines in their metal machining, metal cutting and press shops.

The interviews can be conveniently summarized with a simple iso-quant diagram. Firms generally saw their production functions as non-homethetic, subject to economies of scale. The optimal capital-labor ratios increase with scale. The iso-quants are sharply curved, indicating quite limited possibilities for capital-labor substitution (see Figure I).

FIGURE I

A Typical Production Function as Perceived by Multinationals in Brazil



3. Satisficing and Technological Transfer

The interviews suggest that firms replicate plants producing at the same scale elsewhere, with only minor modifications for lower wages. Does this choice accurately reflect the full range of technological alternatives? Or does it arise, at least partially, from the limited technological search undertaken by foreign firms? There is evidence in our interviews for the latter interpretation. When asked whether the practices of similar firms elsewhere were investigated in designing the Brazilian plant, most subsidiaries answered that they consulted only other branches of the same multinational firm, normally, in the home country, or sometimes if the firm was American, in Europe. A broad search for new methods, particularly in low wage countries,[1] was never attempted.[2] Foreign firms may not be employing "optimal" methods in Brazil, but merely the old familiar tehcniques.

There are at least two ways to test for optimality. One could determine optimal techniques and compare them directly with those employed by multinationals. Louis T. Wells did this in Indonesia, and found a tendency for firms, particularly foreign firms, to employ excessivley "modern" or capital intensivve methods.[3] His sample size is so small, however, that generalizations are difficult to extract.

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[1] No one, for example, studied Japanese methods - except the Japanese.

[2] Wickham Skinner found a similar lack of search of U.S. multinationals. See Wickham Skinner, American Industry in Developing Economies: The Management of International Manufacturing (New York: 1968), pp. 147-150.

[3] See Louis T. Wells, op. cit. especially Table II. As Stated in the introduction, Wells attributes this choice to the "engineers" and the monopoly power of the fireign firms.

Our approach is to assume a satisficing/managerial discretion model of technological choice. If multinationals transfer the production methods they "know best," we may then expect to find significant differences between American, European and Brazilian firms. We tested for such differences using 1969 Brazilian Industrial Survey data at the establishment level.

The outlines of the technological satsificing/managerial discretion model are fairly simple. Assume a smooth production function for a given product. Furthermore, assume that on the average management differs across countries in its ability to combine labor and capital efficiently. Then we can write for a "tyical plant" managed by the ith country:

$$Q_i = F(K,L,\lambda_i) \qquad i = 1,2,3 = \text{country management}$$

$$= \lambda_i F(K,L) \qquad \lambda_i = \text{the management efficiency parameter for the ith country}$$

Casual empiricism of the Servan - Schreiber variety suggests that on the average American firms may be more efficient operationally than West European firms, which in turn are almost certainly more efficient than the typical Brazilian firm. Thus, our working hypothesis is that

$$\lambda_{US} > \lambda_{WE} > \lambda_{BR},$$

where the subscripts have their obvious meaning.

At any point in time λ_i may depend on the current capital-labor ratio. That is to say, management should be most efficient, given its accumulated experience, at existing capital-labor ratios, and the further K/L departs from current levels, the lower λ_i is likely to become. Similarly, λ_i may depend on the average scale of operations. The further scale departs from that at which most experience has been accumulated, the lower λ_i for that nationality may become. That is,

$$\lambda_i = f_i(\frac{K}{L}, Q)$$

$$\lambda_{i\text{-max}} = f_i[(\frac{\bar{K}}{L})_i, \bar{Q}_i]$$

where the bars indicate current levels in the home country.

Now the difference between λ_i and $\lambda_{i\text{-max}}$ may be a declining function of the time elapsed since the introduction of the less familiar techniques. The long-run, static λ_i may be independent of both scale and K/L. Sooner or later efficiency may reach the level previously achieved in the home country. It is perhaps more plausible that superior (say) American efficiency is partially inseparable from large-scale, mechanized operations. Fortunately, the issue is not crucial in this context.

The important point is that costs measured in terms of managerial inefficiency are greater the greater the departure from tried and true methods. Furthermore, these costs are by and large unknown. The only way to determine them is through experience, although rough estimates could be made in principle.

On the other side of the ledger are search costs involved in discovering and mounting techniques differing substantially from those already employed by the firm. A rough approximation would assume that search and set-up costs are an increasing function of the difference between the capital-labor ratio and scale to be "discovered" and those in which experience of the firm has been obtained. The pay-offs to finding new labor intensive techniques are of uncertain values and cannot be estimated accurately in advance.

Thus technological transfer to a low-wage, small-market country seems to be a prime candidate for behavior which satisfices managerial aspirations.[1] These aspirations may have several components. They would certainly contain some target rates of return. They may also contain strictly managerial goals - large staffs and organizational slack,[2] technological virtuosity,[3] etc.

Complete knowledge of the environment cannot be obtained for the decision. Management explores what it already knows, and gathers additional, easily obtainable information. If before exhausting this latter set, aspiration levels can already be satisfied, aspirations will likely be adjusted upward and further search undertaken. At some point perceived information costs begin to rise sharply, and the best feasible alternative which meets aspiration levels is chosen. One might speculate that profit targets are easily met with little search, management will then undertake to make life easy for itself, maintaining

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[1]On satisficing see James G. March and Herbert A. Simon, op. cit., pp. 140-141.

[2]For an application of this concept to the evolution of the multidivisional form of corporate structure, see Oliver E. Williamson, Corporate Control and Business Behavior (Englewood Cliffs: 1970).

[3]This is emphasized, of course, by John Kenneth Galbraith.

large staffs and, more important for present purposes, duplicating to a considerable degree the methods which it knows best. If profit targets are more difficult to fulfill, less room exists for management goals and additional search is required.

Let us apply this framework to technological choice in Brazil. The first thing to note is that the Brazilian economic environment since 1950 has been "permissive." Trade controls, often prohibitive, sheltered local producers against import competition.[1] Rapid growth created a sellers' market in many areas, and price competition was not an important feature of most business behavior.[2] Hence, erroneous decisions on the labor intensity of production were not likely to generate substantial negative feedback through frustrated profit aspirations. For many years this environment probably gave considerable leeway for decisions satisfying strictly managerial goals.

Satisficing, with managerial discretion, should lead to rather different outcomes for multinationals as opposed to Brazilian firms. Multinationals have technological experience built up in a product line developed for large scale operations in high wage countries. The further the technology differs from these conditions, the greater the search and set-up costs, the greater the (perhaps temporary) loss in managerial efficiency, the greater the "bother" management must undergo. If profit aspirations can be reasonably well satisfied

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[1]See Joel Bergsman, Brazil: Industrialization and Trade Policies, (London: 1970), chapter 3.

[2]Joel Bergsman, "Commercial Policy, Allocative Efficiency, and X-Efficiency," Quarterly Journal of Economics, forthcoming, finds considerable evidence that non-aggressive, live-and-let-live behavior dominated much of Brazil's tarrif-sheltered industry.

without incurring these costs, and the Brazilian market was permissive in this respect, management will go with the tried and true.

Adaptations to scale had to be undertaken, but as pointed out above, there is no evidence from our interviews that this search extended much beyond the firm itself, certainly not into the low wage markets of the world. Most multinationals should use the smaller scale methods employed in their home markets.[1] These, in turn, should reflect wage/user cost of capital at the time they were developed in the home country.

It is reasonable, then, to expect significant differences between technologies employed in Brazil by different nationalities of firms. For any given scale of output in Brazil, $\bar{Q}$, we might expect the following:

$$\bar{Q}_i = \lambda_i(K_i, L_i) \qquad i = US, WE \qquad \lambda_{US} > \lambda_{WE}$$

$$\left(\frac{K}{L}\right)_i = \emptyset\left[\left(\frac{W}{r}\right)_i, \left(\frac{W}{r}\right)_{Br}\right] \qquad w = \text{wage}, \quad r = \text{user cost of capital}$$

Since $\left(\frac{W}{r}\right)_{US} > \left(\frac{W}{r}\right)_{WE}$, $\left(\frac{K}{L}\right)_{US}$ should exceed $\left(\frac{K}{L}\right)_{WE}$, and $\left(\frac{\text{Value Added}}{\text{Worker}}\right)_i = \lambda_i\left(\frac{K}{L}\right)_i$.

Therefore, $\left(\frac{\text{Value Added}}{\text{Worker}}\right)_{US} > \left(\frac{\text{Value Added}}{\text{Worker}}\right)_{WE}$.

U.S. based firms should employ more capital per worker and obtain more value added per worker than the West Europeans. Note that the differences in efficiency parameters and capital-labor ratios operate of relative profitability in opposite directions.

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[1]For truly multinational firms this observation is less accurate. But even a number of these seem to duplicate home country methods to a considerable extent in <u>all</u> their operations.

The situation of the Brazilian firm stands in strong contrast. Its knowledge set was developed in a low-wage, small market, but most likely in other product lines. Search costs may be higher for the Brazilian firm, but if it is to meet aspirations, more extensive search is probably unavoidable. Furthermore, local firms probably believe they are operationally less efficient, and therefore they are likely to give greater weight to the proper choice of factor proportions. Thus a satisficing Brazilian firm may be expected to employ less capital per worker, and this, combined with lower managerial efficiency, would keep the value added/worker of local firms below the levels of multinationals. Note that this does not result from optimizing behavior on the part of Brazilians as opposed to non-optimization by foreigners. Rather the accumulated experience of the two groups is the prime determinant. To put it another way, the potential operational efficiency of multinationals permits inefficiency in the choice of technology, while managerial ineffiencies on the part of local firms make greater efficiency in the choice of machines and methods mandatory.

Some empirical evidence on the extent of search and the reliance of multinationals on home-country technology can be gleened from figures on the sources of imported machinery by the nationality of the controlling firm. Data on projects over CR$5 million approved in 1972 for duty-free importation of machinery and exemption from local taxes appear in Table III.[1] The pattern is striking. Each nationality, except the Swiss and the French, imported more than 50% of its equipment from the home country. No nationality of foreign firm imported more than 28% of its equipment from other than home countries. The Japanese and

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[1]It is faily easy for a project to qualify - the set of industries covered is very broad, and the criteria applied by the Comissão de Desenvoluimento Industrial are quite liberal.

Italians were particularly extreme in their concentration on their own equipment.

TABLE III

Percentage of Total Machinery Imports to Brazil Originating from Various Countries, by Nationality of Controlling Group: Projects Approved by CDI in 1972[a] with Total Value Exceeding CR$5 Million

Firm Nationality \ Country from which Imported	U.S.	Germany	Japan	France	Italy	Switzerland	Sweden
Brazil	28.0	27.9	.3	9.6	14.8	5.8	0
U.S.	60.3	22.6	.4	0	3.6	.2	0
Germany	10.2	70.2	0	0	2.3	12.5	0
Japan	7.8	7.0	78.2	0	0	3.4	0
France	27.4	27.5	.9	35.1	5.6	3.5	0
Italy	10.7	1.7	0	0	82.4	4.8	0
Switzerland	.6	95.6	0	0	0	3.8	0
Sweden	0	28.0	3.4	0	0	0	68.0

[a] CDI, the Industrial Development Commission, approves duty free import of machines.
Source: CDI project summaries as tabulated by IPEA/INPES, Industrial Sector.

By far the most diversified importer was the Brazilian firm, probably an indication of greater search and consistent with the satisficing model set forth above. In this respect it is important to note that R. Hal Mason also found that locals procurred from much more varied sources than U.S. firms in his sample twenty-eight enterprises in the Philippines and Mexico.[1]

"Satisficing-type" statements abound in the interviews. One aim of a diesel engine manufacturer was to make methods identical to those in (home country). An automaker claimed not to make detailed comparisons between the total costs of alternate types of machines in performing a task, but rather relied on experience in (home country). A tractor maker claimed to be ignoring labor cost differentials entirely in choosing machines, since Brazilian wages were expected to be high as in (home country) by five years anyway![2] One bearings manufacturer was aiming to use exactly the same machines in Brazil as in (home country), another claimed to use "super modern" equipment, even more automatic than in (home country), a plus for the Brazilian subsidiary. A tire plant was said to be a virtual copy of the latest model in the home country. The list could be considerably lengthened.

It is probably impossible to separate truly satisficing behavior from <u>maximizing</u> behavior which gives heavy weight to managerial slack and/or technological sophistication in a permissive environment. Nor is this crucial. Both could lead to systematic differences across nationalities in the technology employed in Brazil. Furthermore, we do not mean to suggest that <u>all</u> firms act in the manner set forth. Rather this is an "as if" model to explain central tendencies.

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[1]R. Hal Mason, "Some Observations on the Choice of Technology by Multinational Firms in Developing Countries," <u>Review of Economics and Statistics</u>, August, 1973, p. 352.

[2]This implied a 40% per year rise in real labor costs in Brazil!

The same prediction about capital intensities and value added would result if firms of different nationalities were optimizing but faced systematically different costs of funds. This is most serious for comparisons of foreign and Brazilian firms. Small Brazilian firms are small. Small foreign subsidiaries are part of generally much larger firms with better access to capital markets. This could generate greater labor intensity on the part of Brazilian firms. As we move to the larger size categories it is not clear that differences in labor use due solely to differential costs of capital will be observed. Larger Brazilian firms have often enjoyed preferential access to official (subsidized) credit and have benefitted from suppliers' credit for machinery imports. Duty-free importation of equipment has been the rule. We know of no serious study of the differential credit and exchange costs to domestic and foreign firms in Brazil. It seems reasonable to believe that even in the larger categories, the cost of funds to multinationals is lower than to Brazilian firms.

The differences between U.S. and West European firms, however, should be small. In any case, if our interviews are representative, capital charges should not have made much difference in technique.

4. Empirical Results

The argument of the previous section suggests that firm nationality may make a difference. Foreign firms at <u>each</u> scale should use more capital and be more efficient than Brazilian firms. To test this, we performed analyses of variance of value added per worker and a capital proxy, electrical energy per worker, in all Brazilian four-digit industries containing sufficient observations. Furthermore, American firms should be more capital-intensive and more efficient, on the average, than

European firms of the same size. These and the previous hypotheses were tested at the Brazilian five-digit level, employing pairs of establishments as observations in sign tests. In all cases, we used the Brazilian government's Industrial Survey (the "Pesquisa Industrial") establishment data for 1969. Classification of manufacturing establishments by nationality of control was made according to Guia Interinvest (Rio de Janeiro: 1970). In general, any firm with at least 40% foreign control was considered foreign. Finally, only the seven states of Brazil's more developed Center-South were included.

A. Analyses of Variance: Differences between Brazilian and foreign firms.

Formally, the analyses of variance were run using regressions with binary, i.e., "dummy" independent variables. In the value-added-per-worker regressions, three-way classification was used -- size, capital-intensity measured by electrical energy per worker, as explained below) and nationality; in industries where the number of observations permitted, interaction was allowed between that nationality and size effects. This permits the relative efficiency and capital intensities of foreign firms to vary with size. In the capital per worker regressions, the capital intensity cells are, of course, dropped from the list of independent variables.

$$(1) \quad \text{Log} \frac{\text{Value Added}}{\text{No. of Production Workers}} = \alpha + \sum_{i=2}^{n} \beta_i S_i + \sum_{j=2}^{m} \eta_j k_j + \lambda_2 N_2 + \sum_{i=2}^{n} \delta_i N_2 S_i \qquad (1)$$

$$(2)\ \text{Log}\ (k) = a + \sum_{i=2}^{n} B_i S_i + l_2 N_2 + \sum_{i=2}^{n} d_1 N_2 S_i \qquad (2)$$

S_i = the ith size cateogry, i=1...n

k_j = the jth capital/worker category

k = capital/production worker

N_2 = 1 if the firm is foreign, 0 if Brazilian

$N_2 S_i$ = interaction of foreignnes with size.

All independent variables are (0,1) —— 1, if the establishment belongs to the cell, 0 otherwise.

All dependent variables were transformed into logs. This assumes that the effect of each capital intensity cell is a constant percentage across all size groups and nationalities, and that, when the number of observations does not permit interactions, the nationality effect is a constant in percentage terms across all capital intensities and size groups. Hence, the basic production function is assumed to be homothetic, except in the efficiency parameter when interaction terms are included. Particularly in the light of our interviews, homotheticity does not seem warranted, since the capital intensity elasticity should depend on size. Computational problems in Brazil precluded the introduction of terms for the interaction of capital intensity and size.[1] In any case, no other restrictions were placed on the form of the underlying production function. The elasticity of substitution is free to vary with capital intensity, and returns to scale, if any, need not follow any pre-specified functional form.[2]

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[1]We were competing with the 1970 census for access to programmers and computer time in IBGE's data processing section. Only one pass at the regressions was possible, and non-homotheticity in the capital variable was not part of it.

[2]With very large samples, the use of many dummies and interaction terms is a good way to estimate complicated, non-linear relationships. Unfortunately, the number of establishments in any four-digit industry rarely exceeded 100; hence we were quite limited on the number of cells we could include.

The coefficients of equation (1) are interpreted as follows. α is the log of value added per production worker of Brazilian firms in the smallest size group and the lowest capital intensity group. β_i represents the increase in this figure due to membership in the ith ($\neq$ smallest size group), η_j the increase belonging to the jth ($\neq$ lowest) capital intensity group, λ_2 the increase from being foreign and δ_i the increase from being foreign and in the ith size groups. A t test of any given coefficient is equivalent to the F test for the significance of the classification in classical analysis of variance.

The anti-log of each coefficient is one plus the percentage which the average member of the specified cell exceeds the value added per worker of the small, low capital intensity, Brazilian controlled establishments. All results are reported in anti-log form.

The number of size and capital intensity cells we used naturally varied from industry to industry, depending on the range of these variables and the distribution of establishments across this range. Three size groups were typical; five was the maximum. Three capital intensity categories were normally employed, although two and four occasionally were necessary.

Size of the establishment was measured by total value added in 1969. This is a better indicator of output than other variables which could have been used, such as the size of the labor force. But it must be admitted that systematic differences in product quality or monopoly power can disturb the relationship between "output" and value added. This is the more likely in the present context since even the Brazilian four-digit level still contains considerable aggregation in some cases.[1]

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[1]There are 321 Brazilian four-digit industries compared with 422 U.S. four-digit industries.

Partially to alleviate this aggregation problem, and also to avoid including the technologically backward part of the (at least) dual economy,[1] all establishments with less than Cr$ 1 million value added in 1969 (about $250,000.) were excluded entirely from the analysis. Most of the excluded observations were Brazilian. Presumably this exclusion also lessens considerably the identification problem introduced by differential finance costs.

Capital intensity, unfortunately, had to be measured in all cases by the value of electrical energy purchased per production worker. We had planned to use the 1970 Industrial Census in our work, but the census was delayed more than a year in its completion (to March, 1974). The 1969 Industrial Survey included no conceivable proxy for capital other than electrical energy. Suffice it to say here that electrical energy correlates quite well with installed horsepower and suffers the same basic shortcomings as a proxy of capital services.[2]

Finally, all governmentally-controlled enterprises were excluded from our regressions.

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[1]See Richard R. Nelson, "A "Diffusion" Model of International Productivity Differences in Manufacturing Industry," American Economic Review, Dec., 1968, pp. 1219-1248.

[2]Griliches used installed horsepower to estimate U.S. manufacturing production functions for 1954. Although its coefficients were highly significant, they seemed to be biased downwards because of measurement errors. See Zvi Griliches, "Production Functions in Manufacturing: Some Preliminary Results," in Murray Brown (ed.), The Theory and Empirical Analysis of Production (New York: 1967), pp. 304-307. In the 1950 Brazilian Census of Manufactures (Censo Industrial), the rank correlation of electrical energy purchased/worker with installed horsepower per worker across 10 size categories in the metal-working industries was .96. Furthermore, in the U.S. Census of Manufactures, the rank correlation at the two-digit level between the rates of growth, 1954-1962, of electrical energy purchased and installed horsepower was .85. Neither measure includes buildings, but their principal defect seems to be their identification of power with capital value, clearly incorrect for sophisticated modern equipment. But book value as a measure of "capital" also suffers severe defects, all the worse in an inflationary environment.

TABLE IV

Significant Regressions, Value Added per Production Worker
Antilog Form

Cr$ thousand, 1969

Variable \ Industry	Ferrous and non-ferrous foundries	Non-electric equipment for hydraulic, thermal, ventilation & refrigeration plants	Industrial machines and machine tools
Constant	17.18	19.86	19.58
Size group			
2	1.305 (10%)[b]	1.583 (5%)	excluded[a]
3	1.204 (no)	1.272 (16%)	1.9333 (1%)
4			
Electrical Energy			
2			1.243 (2.5%)
3			1.472 (2.5%)
4			
Foreign	1.448 (5%)	1.269 (10%)	1.244 (6%)
Foreign-size interaction			
F x 2	.866 (no)		1.289 (10%)
F x 3		1.173 (no)	.702 (15%)
F x 4			
R^2	.13	.25	.22
D.F.	54	50	115

[a] Not significant, excluded in final form.

[b] Number in parenthesis is the (one-tail) significance level of the coefficient.

TABLE IV (continued)

Variable \ Industry	Electrical wires and Cables	Auto Parts	Inorganic Chemical Products
Constant	20.72	18.36	29.10
Size group			
2	1.677 (5%)[b]	excluded[a]	excluded[a]
3		excluded[a]	1.734 (2.5%)[c]
4		2.153 (.5%)	
Electrical Energy			
2	2.425 (4%)		
3	4.548 (2.5%)		
4			
Foreign	1.049 (no)	1.260 (4%)	1.460 (2.5%)
Foreign-size interaction			
F x 2		1.278 (13%)	
F x 3		1.356 (3%)	
F x 4			
R^2	.48	.30	.27
D.F.	13	123	35

[a]Not significant, excluded in final form.

[b]Number in parenthesis is the (one-tail) significance level of the coefficient.

[c]All firms in this size group are foreign.

TABLE IV (Continued)

Variable \ Industry	Vegetable fats and oils	Paints and Varnishes	Pharmaceutical and medicinal Products	Plastic prods. excluding those made from bakelite, ebonite, and galatite
Constant	30.52	36.09	40.24	17.60
Size group				
2	2.292 (.5%)[b]	1.227 (16%)	1.538 (.5%)	2.361 (.5%)
3	12.83 (.5%)		1.816 (.5%)	1.966 (.5%)
4			2.414 (.5%)	
5			1.545 (5%)[c]	
Electrical Energy				
2		1.504 (1%)		excluded[a]
3				1.597 (1%)
4				
Foreign	.5499 (5%)	1.677 (.5%)	1.741 (2.5%)	1.442 (2.5%)
Foreign-size interaction				
F x 2			.674 (12%)	excluded[a]
F x 3			.869 (no)	excluded[a]
F x 4			.567 (6%)	
R^2	.73	.44	.35	.36
D.F.	25	29	111	65

[a] excluded = not significant, excluded in final form.

[b] Number in parenthesis is the (one-tail) significance level of the coefficient.

[c] All firms in this size group are foreign.

(When an entry is left blank, this means the variable was not included in the regression.)

TABLE V

Significant Regressions, Electrical Energy Purchased Per Worker, Anti-log Form

Cr $1969

Industry / Variable	Ferrous and non-ferrous foundries	Industrial Machines and Machine Tools	Parts and accessories for Industrial Machines
Constant	174	224	175
Size Group			
2	1.937 (2.5%)	.738 (2.5%)	1.715 (2.5%)
3	2.650 (5%)[b]	1.196 (15%)	
4			
Foreign	1.684 (7%)	1.200 (7%)	1.222 (15%)
Foreign-size Interaction			
F x 2	1.902 (15%)	Excluded[a]	
F x 3		Excluded[a]	
F x 4			
R^2	.30	.07	.23
D.F.	54	117	29

[a] Excluded - not significant, excluded in final form.
[b] Number in parenthesis is the (one-tail) significance level of the coefficient.
(When an entry is left blank, this means the variable was not included in the regression.)

TABLE V (Continued)

Variable / Industry	Machinery & Equipment for Industrial and Commercial Installations	Electrical Generators, Motors and Transformers	Pharmaceutical and Medicinal Products
Constant	176	164	178
Size Group			
2	.861 (5%)[b]	1.691 (10%)	1.299 (7%)
3		1.773 (5%)	1.619 (1%)
4			1.430 (2%)
5			1.727 (.5%)
Foreign	1.628 (.5%)	1.901 (1%)	Excluded[a]
Foreign-Size Interaction			
F x 2	Excluded		Excluded[a]
F x 3			Excluded[a]
F x 4			Excluded[a]
R^2	.17	.31	.18
D.F.	43	37	115

[a]Excluded -not significant, excluded in final form.
[b]Number in parenthesis is the (one-tail) significance level of the coefficient.
(When an entry is left blank, this means the variable was not included in the regression.)

TABLE V (Continued

Variable \ Industry	Electric Wire and Cables	Television, Radios, Phono-graphs, Tubes	Auto Parts
Constant	807	142	287
Size Group			
2	.787 (no)	Excluded	1.128 (no)
3			1.643 (1%)
4			2.268 (1%)
Foreign	2.010 (2.5%)[b]	2.045 (3%)	1.271 (4%)
Foreign-Size Interaction			
F x 2			Excluded[a]
F x 3			Excluded[a]
F x 4			
R^2	.29	.18	.23
D.F.	15	19	124

[a] Excluded - not significant, excluded in final form.
[b] Number in parenthesis is the (one-tail) significance level of the coefficient.
(When an entry is left blank, this means the variable was not included in the regression.)

The regressions were run for nineteen four-digit industry groupings, four of which (foundries and rolling mills) were grouped into two. Many important industries could not be included. Either the number of observations was far too small - automaking, tires, tobacco - or the sector was almost entirely Brazilian or foreign. Examples of the latter were, in addition to the previously mentioned three, textiles (Brazilian), food (Brazilian) and basic steel (public enterprises). As a result, the very largest foreign firms - VW, GM, Ford, British-American Tobacco, Mercedes-Benz, etc. - are absent from the regres sions. (But they do appear in the sign tests reported below).

In ten of the seventeen value-added regressions and nine of the electrical energy regressions the R^2's were significant at the 5% level or better (see Tables IV and V). In the remaining cases size, foreignness and our proxy for capital explain practically none of the variations across establishments. Apparently there is a great deal of noise in the data or other excluded variables, such as plant and equipment vintage, are important.[1]

In spite of this, there is support for the hypothesis that technologies differ. In eight of the nine significant "capital intensity" regressions, foreign firms used more electrical energy per worker than Brazilian firms, when size was controlled although in one case the foreign dummy was significant only at the 15% level. Furthermore, the size-foreign interaction terms are significant in only one of the five industries in which they could be included, ferrous and non-ferrous foundry products. There was usually no systematic difference in the foreign effect on capital intensity as size increased. This suggests, following the discussion at the end of section III, that differential finance costs may not be an imporant factor in-

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[1]Griliches and Ringstad, also working with disaggregated establishment data for Norway, obtained equally "pitiful" R^2's. See Zvi Griliches and Vidar Ringstad, Economies of Scale and the Form of the Production Function (Amsterdam: 1971), Chapter 4.

fluencing capital intensity, at least at the larger sizes included in our sample. It is also important to note that in none of the industries did foreign firms use significantly less electrical energy per worker than Brazilian firms. One suspects that the results would have been better with a more accurate measure of capital. In particular, foreign and large firms probably use more modern machinery on the average, so that their capital services/electrical energy is likely to be higher. Thus, our specification seems, if anything, biased against significance.

A similar picture emerges from the value added per worker regressions. In eight of the ten cases, the foreign efficiency parameter was significantly larger than one at the 10% level or better, in only one (vegetable fats and oils) was it significantly less than one. In electrical wires and cables, size and capital intensity alone were significant, but foreign firms were significantly more capital intensive than their Brazilian counterparts.

The size dummies usually possessed considerable explanatory power, and in every industry at least one size dummy was significant. In five of the ten industries economies of scale were present even up to the largest size category. In four of these five - industrial machines and machine tools, auto parts, basic inorganic chemicals and vegetable fats and oils - the coefficient of the largest size group is significantly greater than that of the immediately preceding cell.

Our capital intensity variable worked well in only three of the ten industries - industrial machines and machine tools, electric wires and cables, and paints and varnishes. In these three all energy coefficients were significant at the 4% level or better, and they increased in value with the "energy intensity" of the category. In the remaining sectors, energy contributed practically nothing to the regression.

The most likely explanation for this state of affairs is again the crudeness of the capital measure, aggravated perhaps by a correlation between size and foreignness and the "true" measure of capital intensity. That is, size and foreignness together may in some industries serve as a better proxy for capital intensity than electrical energy per worker does. The size and foreignness coefficients will likely "pick-up" some of the capital effect, and will be biased upwards. Errors in measurement will bias downwards the electrical energy coefficients and lead to their insignificance.

The size effects. per se, are of minor importance for our purposes. But in general, the foreign parameters should be upper estimates of "pure efficiency" differentials, which probably explains their sometimes unreasonably large values.

The interaction terms were significant in only three industries - industrial machines and machine tools, auto parts and pharmaceuticals. In auto parts, the value added of larger foreign establishments is relatively greater than those in the smallest size group, while in pharmaceuticals exactly the reverse occurs. There is no pattern at all in industrial machinery. No conclusive evidence here as to whether foreign enterprise excells relatively more in larger scale operations.

In summary, in about half of the industries examined foreign firms used significantly more electrical energy per worker and attained a higher value added per worker when size was controlled. In the three industries where electrical energy per worker performs well as a capital intensity proxy, foreign firms appear to be more efficient than Brazilian firms, on the average, while in the other cases it is probably impossible to separate the efficiency

effects of foreignness from its tendency to be associated from more capital intensive processes.

B. Differences between foreign firms

Differential capital costs may still be cited as a partial explanation of the pattern we encountered in the previous section. Capital costs should be much less important in explaining variations across nationalities foreign firms for two reasons. First, international enterprises of the type operating in Brazil face fairly similar capital costs. But even if they did not, our interviews suggest that multinationals are insensitive to capital costs in choosing their production techniques. Hence systematic differences between different nationalities of foreign firms may be taken as clearer evidence of satisficing/managerial discretionary behavior.

In most four-digit industries, the number of foreign firms is too small for an analysis of variance. And the two-digit level is too aggregative for present purposes. Hence we tried two other approaches. When data permitted, for each size category in each four-digit industry we tested the hypothesis that the median value added per worker and electrical energy per worker were at least as large for West European firms as for American. Rejecting this permits acceptance of the alternative that American firms show significantly higher values for both characteristics. The Mann-Whitney U-test was used.[1] A summary of the results appears in Table VI.

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[1]A powerful non-parametric test for differences in central tendency. See Signey Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: 1956), pp. 116-126.

TABLE VI

Summary of Tests[a] for Differences Between U.S. and European Firms in Brazil: 1969

	No. of Size Categories in Which U.S. was Larger at 11.4% level or better	No. of Size Categories in Which W. Europe was Larger at 11.4% level or better	No. of Size Categories with No Significant Difference
Value Added Per Production Worker	8	0	15
Electrical Energy Per Production Worker	3	0	20

[a] Using Mann-Whitney U-Test. Includes all size categories with at least two U.S. and two West European firms.

Again the evidence is mixed. Value added per worker differences are significant in the expected direction in only one third of the size categories. The low figure reflects in part the small number of observations in many cells. In addition, this approach yields little support for the view that American firms use more electrical energy per worker than their European counterparts. If electrical energy were an accurate measure of capital intensity, this would be fairly strong evidence that American firms are more efficient in combining resources than the Europeans in many of the industries examined. But energy varies so erratically in relation to value added that it is difficult to believe that large errors in measurement are not present.

Excessive aggregation may also create noise in the data. To deal more effectively with this problem, we tried our second approach. We paired establishments of two different nationalities in the same <u>five</u> digit industry and of

roughly the same total value added.[1] As many five-digit industries were included as the data permitted, but usually only the largest establishments could be sampled. Separate pairings were made between American and German, American and West European (excluding Germany), American and Brazilian and West European and Brazilian firms. The sign test[2] was used to determine whether value added per worker and electrical energy per worker differed significantly between nationalities in the direction predicted by the satisficing/managerial discretion hypothesis.

A summary of the several pairings appears in Table VII. The picture here is more clear-cut, perhaps due to the greater disaggregation. In the value added per worker pairings, all of the differences run in the way predicted by the satisficing/managerial discretion hypothesis and are significant at the 5% level or better. With electrical energy per worker, the U.S.-West Germany pairings are significant (1%) in the direction predicted. But in the others, no significant differences were detected.

Our tentative interpretation of the results is as follows. The significant differences in value added per worker probably represent <u>both</u> capital intensity and efficiency effects. The very spotty performance of electrical energy as a capital proxy is due primarily to its crudeness. Other studies, including a recent paper by R. Hal Mason, which contain comparative data on foreign and domestic firms in LDC's show greater capital intensity in the in foreign

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[1]Each observation was paired with another, the value added of which was most nearly equal to it. In only one case did a pair differ in total value added by a factor greater than two. Usually the differences were <u>much</u> smaller.

[2]See Sidney Siegel, <u>op. cit.</u>, pp. 68-75 for a good description of the test.

TABLE VII

Results of Sign Tests for Significant Differences Between Nationalities at the Five-Digit Level

Number of Pairings in which:	Value Added Per Production Worker	Electrical Energy Per Production Worker
U.S. > Brazil	23	14
Brazil > U.S.	4	10
Ties	2	4
Significance	1%	not significant
U.S. > W. Germany	19	22
W. Germany > U.S.	10	5
Ties	0	2
Significance	5%	1%
U.S. > W. Europe (excluding Germany)	16	12
W. Europe > U.S. (excluding Germany) (excluding	6	9
Ties	2	3
Significance	5%	not significant
W. Europe > Brazil	14	8
Brazil > W. Europe	5	11
Ties	0	0
Significance	5%	not significant

TABLE VIII

Average Profit Rates Before Taxes of Corporations,[a] 1973, by Nationality of Firm

	Brazil	U.S.	W. Europe
Metals and Machinery	19.7 (32)	17.6 (10)	18.0 (9)
Autos and Auto Related	18.8 (11)	22.2 (15)	15.9 (12)
Electrical Equipment	23.8 (7)	11.6[b] (6)	11.3 (11)
Chemicals, Paper and Plastics	14.0 (17)	8.6 (14)	7.6 (13)

[a]Only firms included in DEICOM's 1969 cadaster were included in the calculations.

[b]Excludes Standard Electrica, S.A., with a loss of 162.6% of net worth. Numbers in parentheses are the number of firms included.

Source of Original Figures: Brazil Report, 1973 Edition (São Paulo, Visão, S.A. Editorial).

subsidiaries.[1] We feel fairly confident that a similar result would have emerged more clearly for Brazil had better data been available.

Furthermore, if the significant differences in value added per worker were due only to the efficiency parameter, the profits of American firms should be higher than those of other nationalities, and the profits of Brazilian firms should be smallest of all. There is no evidence of this (see Table VIII). If anything, published balance sheets for corporations in Brazil support the view that no

[1]See, for example, R. Hal Mason, op. cit.: Loretta Louise Goode, United States Joint Ventures and National Manufacturing Firms in Monterrey, Mexico: Comparative Styles of Management (Cornell University Latin American Studies Program Dissertation Series, no. 37, August, 1972), p. 135; Louis T. Wells, op. cit., p. 323.

significant differences in profit rates before taxes exists between the various nationalities in the activities we have examined. No great credence can be placed in these profit figures for a variety of reasons. Still, the figures are consistent with other evidence suggesting that value added per worker differences reflect a profit increasing effect for foreign firms - greater efficiency - and a profit decreasing effect - excessive capital intensity.

5. Policy Implications

Definitive conclusions from the various empirical strands cannot be drawn. But the evidence strongly suggests satisficing and managerial discretion in the choice of production methods. If this is correct, several policy implications follow.

(1) If LDC's want multinationals to employ more labor-intensive methods, they should be prepared to reduce the permissiveness of the environment. This means allowing greater competition from imports and avoiding "overkill" in granting favors to attract foreign firms.

(2) Once profits become more difficult, multinationals may be expected to pay greater attention to optimal production methods, to engage in greater technological search. They may also be more responsive to labor subsidies designed to bring market prices of factors more in line with their social opportunity costs.

(3) On the other hand, if LDC's are permissive and insist on developing industries which are capital-intensive by their nature---this seems to be the case with Brazil until now---they should not be surprised that multinationals do not employ more labor.

APPENDIX

List of Firms Interviewed

1. Autos and Trucks
   - General Motors[1]
   - Ford
   - Chrysler
   - Volkswagon
   - Mercedes-Benz

2. Auto Parts
   - Bendix do Brasil (U.S.)[1]
   - Federal Mogul (U.S.)[1]
   - Sifco (U.S.)
   - NGK (Japan)

3. Tractors
   - Caterpillar
   - Massey-Ferguson (Canada)

4. Diesel Engines
   - Perkins (U.K.)
   - Yanmar (Japan)
   - MWM (German)

5. Machinery
   - Worthington (U.S.)
   - Barber-Greende (U.S.)[1]
   - Falkdo Brasil (U.S.)[1]
   - Freiose Sinais do Brasil (Westinghouse Air Brake)[1]

6. Business Machines
   - IBM
   - NCR (U.S.)[1]

7. Bearings
   - Timken (U.S.)
   - N.S.K. (Japan)

8. Telecommunications
   - Standard Electrica (ITT)
   - NEC (Japan)
   - Plessey (U.K.)

9. Electrical Equipment
   - Hitachi-Line (Japan)
   - Eletromar (Westinghouse)

10. Domestic Appliances
    - Telefunken (Germany)
    - Philco-Ford
    - General Electric[1]

11. Rubber Tires
    - Goodyear (two plants)
    - Firestone

12. Textiles
    - Sudamtex (U.S.)

13. Vegetable Oils
    - Anderson-Clayton (Houston)

14. Cigarettes
    - Liggett and Meyers (U.S.)

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[1] Included in in-depth plant comparisons between U.S. and Brazil.

PROGRAM OF DEVELOPMENT STUDIES
Discussion Papers

40. "A Note on Z Goods, Marketed Surplus and the Labor Intensity of Small Farm Agriculture" (1973), 22 pp., Wayne R. Thirsk.

41. "The Incidence of Colombian Taxes, 1970" (1973), 66 pp., Charles E. McLure, Jr.

42. "What to Do about Foreign Direct Investment: A Host Country Perspective" (1973), 28 pp., Samuel A. Morley.

43. "Income Distribution Consequences of Agricultural Price Supports in Colombia" (1973), 32 pp., Wayne R Thirsk.

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45. "Industrialization in Malaysia: A Penang Micro-Study" (1973), 42 pp., Fred R. von der Mehden.

46. "Short-run Effects of Income Distribution on Some Macro-economic Variables: The Case of Turkey" (1973), 33 pp., Tuncay M. Sunman.

47. "The Inequity of Taxing Iniquity: A Plea for Reduced Sumptuary Taxes in Developing Countries" (1973), 51 pp., C.E. McLure, Jr. and W.R. Thirsk.

48. "A Numerical Exposition of the Hargerber Model of Tax and Expenditure Incidence" (1973), 51 pp., C.E. McLure, Jr. and W.R. Thirsk.

49. "Public Goods and Income Distribution: An Explanatory Comment" (1974), 17 pp., C.E. McLure, Jr.

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51. "Rural Credit and Income Distribution in Colombia" (1974), 26 pp., Wayne R. Thirsk.

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55. "The Within-Nation Distribution of Public Expenditures and Services: A Two-Nation Analysis" (1974), 19 pp., Kim Q. Hill.

56. "Managerial Discretion and the Choice of Technology by Multinational Firms in Brazil" (1974), 37 pp., Samuel A. Morley and Gordon W Smith.

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