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TECHNOLOGY CHOICE AND EMPLOYMENT IN DEVELOPING COUNTRIES: A SYNTHESIS OF ECONOMIC GROWTH CENTER RESEARCH

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Technology Choice and Employment in Developing Countries: A Synthesis of Economic Growth Center Research*

This paper is intended to summarize the major findings of research financed under contract AID/OTR C-1326, including the conclusions for behavior and policy which emanate from that research.[1] We will, in Section I, briefly review the present state of the arts which can now be more or less taken for granted, largely as a reflection of the progress made since the early 1960s. Not only our understanding of the interaction between technology and employment but also the definition of societal objectives has changed, moving beyond growth and employment to the consideration of the distributional and poverty alleviation objectives of developing societies. Section II will be devoted to a summary of the findings of the research financed under this contract and Section III to a summary of the conclusions which flow from these findings.

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[1]It should be emphasized that this Synthesis draws on the four studies performed under this contract, i.e. Mary Ann Baily, "Technology Choice in The Brick and Men's Leather Shoe Industries in Colombia"; Lucy A. Cardwell, "Technology Choice in the Men's Leather Shoe and Cotton Spinning Industries in Brazil: The Relation Between Size, Efficiency and Profitability"; John C.H. Fei, "Technology in a Developing Country: The Case of Taiwan"; and Gustav Ranis and Gary Saxonhouse, "Technology Choice, Adaptation and the Quality Dimension in the Japanese Cotton Textile Industry". Moreover, as is noted in each of the studies, the Growth Center gratefully received the cooperation of a number of institutions and individuals in Brazil, Colombia, Taiwan and Japan. However, none of these is to be held responsible for the conclusions drawn here.

Section I: The State of the Arts

A quick review of progress made in this general area of socio-economic research since the early 60s would certainly include increased recognition, now debated only rarely, that a developing country can substantially adjust its technology for given output mixes, even though the traditional view that output mix choices are much more important has not been substantially shaken. What is new and essential is the recognition of the existence of a fairly wide range of alternative factor proportions for all but a small subset of continuous process industries. Some of this evidence has been presented in the course of earlier Growth Center work[1] as well as in such broader surveys as Morawetz[2], Acharya [3], Bhalla[4], and Ranis[5]. There is therefore no need here to dwell on the by now well documented existence of wide technological choices available in nature. We can, instead, proceed immediately to the central question of why the choices actually made in most poor labor surplus countries are not as different as their substantial endowment gaps would seem to dictate.

A second finding, still somewhat more controversial but also increasingly becoming part of the new conventional wisdom, is the recognition that countries which succeed in taking relatively greater

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[1] See "LDC Employment and Growth: A Synthesis of Economic Growth Center Research," Gustav Ranis, July, 1975.

[2] "Employment Implications of Industrialization in Developing Countries", Economic Journal, September 1974.

[3] "Fiscal/Financial Intervention, Factor Prices and Factor Proportions: A Review of Issues", IBRD, Staff Working Paper #183, 1974.

[4] Technology and Employment in Industry, ILO, 1975.

[5] "Industrial Technology Choice and Employment: A Review of Developing Country Evidence," Interciencia, Vol. 2, No. 1, 1977.

advantage of these wider choices actually available in nature necessarily do not have to "pay a price" or incur a trade-off as economists traditionally would like to have it. Rather, it is not only possible to eliminate a basic conflict between developmental objectives, but, as has been demonstrated at least in the case of a subset of "well behaved" developing countries, such as Taiwan, Korea, and Japan historically, can enhance their growth performance by choosing a combination of output mix and technology changes which absorb increasing volumes of the abundant supply of unskilled labor. Recent related research indicates as well[1] that the distribution of income, another essential dimension of the typical contemporary LDC objective function, does not have to deteriorate during such a period of rapid employment or labor intensive growth. In fact, while this area of inquiry is still much more controversial--see for example the work of Kuznets, Adelman and Morris, Adelman and Robinson etc.,[2] the evidence, at least on Taiwan, indicates that the so called Kuznets inverse U-shaped pattern, i.e. the worsening of income distribution before things can get better in such countries, can also be obviated. Here again, as has been shown elsewhere[3], the choice of labor intensive technologies, especially in the rural areas and in secondary food and non-agricultural activities, is of crucial importance in yielding the mutual reinforcement of the three desirable objectives.

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[1] J.C.H. Fei, G. Ranis, S. Kuo, "Growth and the Family Distribution of Income by Factor Components," Quarterly Journal of Economics, February, 1978, and Equity with Growth: The Taiwan Case, forthcoming.

[2] S. Kuznets, "Economic Growth and Income Equality," American Economic Review, 1955; I. Adelman and C.T. Morris, Economic Growth and Social Equity in Developing Countries, Stanford University Press, 1973; I. Adelman and S. Robinson, Income Distribution Policy in Developing Countries: A Case Study of Korea, Oxford University Press, 1978.

[3] Fei, Ranis and Kuo, op. cit.

It is, moreover, increasingly recognized that the joint achievement of these societal objectives is more likely to take place in relatively small countries and where the typical primary import substitution subphase of transition leads, after some time, to a more liberal or market oriented export substitution subphase in which the chances for labor intensive technology choices and labor using technology biases seem to be substantially better. For the more average developing country of today still heavily engaged in secondary import substitution, e.g. in Latin America, or still in the primary import substitution phase, e.g. in parts of Africa, the evidence suggests that the so-called tradeoffs between growth, employment, and distribution persist. However, previous research at the aggregate level does indicates that policy changes which lead to a lessening of the distortion of the relative prices of inputs and outputs, as well as--and this is an important separate point--increased competitive pressure on firms tending to force them to consider technological alternatives, represent essential ingredients in lessening if not eliminating these tradeoffs. The relevance of the size of countries and thus their ability to substantially shift their output mixes via an increased participation in international trade represents a third general conclusion that the profession has reached to date.

The present research effort is essentially based on this new level of understanding reached in the course of the 60s and early 70s. It is focussed on asking what are the necessary and sufficient conditions for the appropriate technology choices to be made at the micro level so that the successful aggregate behavior pattern that has been observed to date only

in a small subset of deviant developing countries is more likely to be duplicated elsewhere. Recognizing that a more realistic set of price signals and a more competitive environment are essential ingredients of that story, a basic purpose of the present research has been to go beyond this level to explain observed differential performance across countries and across scales of firm operations within countries. It is after all, the action of thousands of entrepreneurs in the mixed economy setting which determines the overall performance with respect to output, employment and the distribution of income. It is the institutional and other non-conventional dimensions of that environment which produce those choices along with the impact of the more narrowly economic, or conventional, dimensions. It was the hope that the investigation of such factors and their incorporation into analyses of technology choice and change at the firm level would permit us to advance our understanding of the reasons for differential technology-related behavior in different types of developing countries and thus lead towards a broadened set of policy conclusions with respect to affecting that behavior.

The above summarizes the basic setting for the research efforts being reported on here. There is, however, one additional, somewhat distinct, component of this effort which must be touched upon at the outset. Increasingly during the past decade some attention has been paid to the appropriateness of goods as opposed to the appropriateness of technology choices for given goods. This gradual realization is

due in large part to the theoretical work by Lancaster[1] followed up and applied to the developing countries, in particular by Frances Stewart[2]. The subject has become increasingly topical in very recent years as the discussion of the provision of the so-called basic needs for developing countries assumed greater importance. This concern with the appropriateness of goods can be translated into the decomposition of a commodity into a bundle of quality characteristics, with planned as opposed to accidental variations in input or output quality, possibly associated with substantial variations in the basic technology choices open to the entrepreneur and to society. The effort to delve into this particular area of quantification of the appropriate goods dimension of the problem led us to an investigation of input and output quality variations in the Japanese cotton textile industry historically as one component of the research effort presently under discussion. The basic premise here is that at any level of SITC classification the assumption of homogeneity in these various bundles of quality characteristics may, in fact, obscure the very important residual source of flexibility in nature which entrepreneurs can take advantage of, given the "proper" conditions both of the conventional and non-conventional variety, as previously defined.

Cutting across both these major blocks of research effort on which we are reporting here is the international dimension affecting technology choice within the country. Here again the state of the arts has substantially advanced during the past decade and a half. We are increasingly aware of the importance of the usually restricted international choice

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[1] "A New Approach to Consumer Theory", Journal of Political Economy, April, 1966.

[2] Technology and Underdevelopment, MacMillan, 1977.

of technologies and the lack of complete illumination as well as institutional access to a wider range of potential alternatives. Simultaneously we have become aware of the importance of the power of domestic adaptations "on top of" imported technology even though the ways in which such adaptive processes are encouraged or discouraged remains something of a mystery. The costs of shelf acquisition, of research, development and indigenous technology change are all subjects which have increasingly gained the attention of researchers and policy makers. Both the contemporary LDC oriented research activities as well as the investigation of the Japanese historical case placed a good deal of their focus on the interactions between the transfer of technology from abroad and the domestic indigenous technology and diffusion processes.

Given the wide choice in nature with respect to output mix, technology and quality we were nevertheless confronted with the fact that the selection actually made in all three dimensions in most of the developing countries still appears to be "inappropriate" by any quantitative or judgemental standard. Certainly while capital/labor ratios differ as between rich and poor countries for given standard goods they differ much less than the differences in factor endowment would lead us to expect. While output mixes as between inherently more capital and labor abundant economies differ they do not differ as much as international trade theory would predict. And certainly while the consumption per capita of the famous drip dry shirts in the developing world is lower than that of the bush shirt, the gap in the choice of appropriateness in the commodities chosen

is again much less than expected on the basis of endowment gaps.

There is a well known litany of causes, both domestic and international, which is customarily cited as part of the explanation. This list is very much like the old fashioned "factors in economic development". Very little effort has been made and even less result achieved in trying to give appropriate weights to the various factors which are more rather than less important in causing the continued gap between textbook optimality and the actual performance of most of the developing countries.

The research activity we shall be reporting on here thus had a three-fold purpose: one, to analyze the process of technology choice and technology change at the individual entrepreneurial level in two or three important industries in three typologically diverse contemporary developing countries with the help of the acquisition of original primary data for these multi-firm industries; two, to search for explanations both in the conventional arena, i.e. within the normal economic calculus, as well as in the non-conventional, e.g. the institutional sphere, of the entrepreneurial choices actually made; three, to further explore the potential of appropriate good selections as well as the technology import, adaptation and diffusion processes in the context of the use of the historical laboratory in the case of the Japanese cotton textile industry.

Section II: Synthesis of Findings

A basic finding emanating from our four-country micro level study of technology choice and technology change must be to candidly admit that the subject is even more difficult to tackle with the help of cross

section analysis than we had anticipated. This is in part due to the fact that while we had hoped to improve upon the data deficiencies customarily encountered in country census data, we had not adequately anticipated the difficulty of deducing something about technology change--as opposed to choice--on the basis of a one-shot observation. Another general conclusion from our contemporary LDC cases is that respondents are not only more leery of the interview process than we had correctly anticipated but are unable to exercise the necessary recall with respect to changes in their production decisions over time, a factor we did not fully appreciate. Thirdly, from the conceptual point of view, we found that the study of technology change in terms of the ability to derive precise quantitative answers is even more difficult than we had imagined precisely because it lies on the frontiers of all economic analysis.

The subject is difficult, in brief, because we are dealing here with a set of phenomena which go beyond the traditional boundaries of economic analysis. Kuznets has long ago identified the epoch of modern growth to which developing countries aspire as the "scientific epoch" which has a strong technological component. In juxtaposition to this, traditional economic analysis considers technology as a strictly economic issue, i.e. within the calculus of the efficiency of resource allocation, factor price distortions, competitive vs. non-competitive behavior etc. within a particular epoch, either of the agrarian (premodern) or of the modern growth variety. The issue of

technology choice and change within a developing country, however, is basically an issue within a system in transition from agrarianism to modern growth, and hence we cannot avoid addressing ourselves to problems not traditionally emphasized. While we are thus aware of the need to search "beyond relative factor prices" we are also chastened by the absence of theory which permits the nontraditional dimensions to be incorporated with traditional dimensions within an overall explanatory framework.

In surveying the main results of our research it is noteworthy therefore that the various approaches utilized all take the traditional resource allocation oriented approach as the point of departure, with a production function, implicit or explicit, as the basic notion with which to tackle technology change and technology choice processes. This is true even of our excursion, in the context of the Japanese textile industry, into an analysis of appropriate goods representing a non-conventional use of a basically conventional apparatus rather than the extension of the conventional apparatus into institutional and/or non-economic arenas.

Our effort in the three developing country cases, Brazil, Colombia and Taiwan, thus begins with a production function oriented approach, with output related to capital and labor, and the extent of substitutability a differentiating feature, e.g. as between the Baily and Fei representations; Baily uses a Leontief type of production function and Fei a neo-classical, substitutable type to capture the production reality in their particular industries and countries. The Ranis/Saxonhouse

specification, on the other hand, involves multiple outputs in terms of output quality differentials as well as multiple intermediate inputs in terms of raw cotton differentials. Given any of these production functions, traditional analysis emphasizes the optimum input/output combinations that lead to the maximization of entrepreneurial profits consistent with an efficient pattern of overall resource allocation from the social point of view. This approach emphasizes the fact that technology choices are induced essentially by input and output price variations on the assumption of rationality and perfect markets facing the entrepreneur. While all our analysis thus contains elements of this rational resources oriented approach, we have tended to go beyond it in a number of important dimensions and with different degrees of success.

As we see it, there are three basic limitations to the traditional approach. One, analyzing production at the aggregate capital/labor production function level obscures the engineering realities which underlie the abstraction of the production function. The second basic limitation of the traditional approach which became increasingly obvious during the course of our research is the identification of the entrepreneur as a rational profit maximizer concerned entirely with the economic environment and the economic calculus within that environment. The third limitation, and admittedly more frequently adjusted for in the so-called conventional literature on technology choice and technology change, is the assumption that the structure of both factor and commodity markets somehow approaches the competitive model.

With respect to the level of aggregation at which technology choice should be examined, our work, especially that on Taiwan, suggests that an

intermediate level of disaggregation between the aggregate firm level production function and the individual tasks a la Boon or Westphal[1] represents a resonably illuminating level at which to operate. This means, for example, in the case of brick manufacture the identification of six or seven major processes (very similar ones emerged in the Colombia and Taiwan analysis of brick manufacturing). Some of these processes have undergone relatively little technology change over time while others, especially the kiln or baking process represented by the kiln technology, have been the focus of substantial change in the past and do afford a substantial array of technology choice at any moment in time. A second step in our analysis has been to identify those processes within the total set which have been the locus for major innovation in that particular industry. By looking at alternative kiln designs in brick manufacturing, alternative machines in textile spinning etc. the ability to analyze realistic technology choices is much enhanced in contrast with the aggregate capital/labor procedure which tends to hide what is actually going on, very much in the way output mix changes tend to obscure technology in a given industry. Only as a summary statement of what is transpiring below the surface does it really make sense to view the efficiency of resource allocation at the aggregate level.

With respect to the normal assumption that the firm in the less developed economy may be presumed to be able to rely upon profit sensitive (and only profit sensitive) entrepreneurs operating in

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[1] G. K. Boon, Economic Choice of Human and Physical Factor in Production, North Holland, 1964; L. Westphal, unpublished material on Korean engineering industries.

impersonal and relatively perfect markets as the basic organizational device, this abstracts from the fact that such countries are, in fact, in the very process of developing entrepreneurial quality as well as perfecting their product and factor markets ; moreover, that it is the very absence of a modicum of such conditions which is likely to stand in the way of the ideal technology choice and the ideal direction of technology change. It is,in fact,the growth of these human capacities that constitutes a significant and policy relevant issue. There can be little doubt that it is the non-market factors which are much more important during the LDC transition growth subphase, and that it is the understanding of decision making which goes beyond the short-term profit maximizing calculus which is likely to illuminate what actually transpires and can explain some of the "puzzling" results previously referred to. It is a change in the production function or the production possibility set which partially describes the technological capacity of a society,and thus it is the engineering reality at the sub-aggregate level which looms large in terms of its significance.

It may thus be said that all the studies presented here represent to some extent a combination of a traditional resources oriented approach with an attempt to break out of these constraints in trying to meet the issues just posed, i.e. a more realistic engineering reality, a more realistic understanding of entrepreneurial capacities and constraints, and a more precise focussing on what particular elements of imperfection in the marketsaffect and effectively constrain the technology choices

made. While we believe to have made some progress we should candidly admit that the unsatisfactory state of theory in dealing with this essentially hybrid effort to imbed traditional theory within a larger institutional framework hampered our ability to come up with hard quantitative findings and conclusions. Finally it should be noted that our attempt to initiate the analysis of the adaptive goods dimension of the problem in the context of our Japanese historical study may be viewed as another effort to move away from traditional analysis, but this time, as we have noted, in a somewhat different direction.

In probing in these various directions we were, moreover, confronted not only with the lack of quality data already referred to but also with the inability to count on data at the appropriate level. The traditional body of data accompanying the conventional level of analysis, e.g. on prices, aggregate output, quantities of inputs etc. is well known. The difficulties encountered in our own primary data collection effort at the process level were much more severe, especially with respect to obtaining a reliable measurement of the capital stock. This was as true in the medium and small scale firms where no formal internal accounting systems exist as in the large firms where there was a good deal of distrust and sometimes clear-cut non-cooperation. But perhaps the most important problem we encountered once again, at this level, is the intrisic difficulty of trying to study technology change, which is a time sensitive phenomenon, via the use of information of a cross sectional variety (with the exception of the Japanese study). In all cases this unavoidable

suppression of the time dimension, except to the extent one could rely on the imperfect memories of individual respondents, proved a major problem.

Even in the best of all possible worlds there is, of course, always the problem of "measurement without theory" and of "theory without measurement". In this particular case, it should be noted, as we move away from conventional theorizing and conventional data these problems are simply compounded. The reward to this interplay or interaction between theory and measurement which takes place in all economic analysis becomes especially problematic when we move beyond the normal frontiers, as we have in this set of studies.

No effort will be made here to summarize all the major findings and conclusions for further research and/or policy for each of the studies carried out under this project. Such summaries are contained in each of the individual studies. What we intend, instead, to do here is to emphasize the major conclusions emerging from each of the studies and to especially highlight the set which seems to recur thematically across the various country and industry cases.

The selection of our countries and industries in the first place was based on a mixture of theoretical and pragmatic considerations. In brief, we wanted to achieve a measure of representativeness across different types of developing countries as well as to look at industries which were not at the continuous process end of the technology spectrum and carried a substantial weight in the total industrial structure of these as well as other similarly situated developing countries. It was also necessary to choose countries in relation to the availability of

interested cooperating institutions and individuals and to try to ensure a minimum of comparability within the small number of studies made possible by virtue of both human and financial resource constraints. In the final analysis the developing countries chosen included Colombia and Brazil (state of São Paulo) in Latin America, and Taiwan in Asia; the industries chosen ex ante included bricks, cotton spinning, men's shoes and machinery. In the course of further negotiations as well as considerations of changes in local feasibility and interest, the men's leather shoes industry was retained in all three country cases, with cotton spinning added in Brazil, bricks in Colombia, and all four industries surveyed in Taiwan.

Since we are interested in the coexistence of differential factor proportions and technology choices across firms of different size and age detailed questionnaires were administered to firms in each of the countries with the size of firm variable a consistent discriminating device. While the questionnaires themselves have a core of comparability across the three country cases our interaction with local institutions and researchers, as well as our recognition of inherent institutional as well as economic differences across countries, dictated a substantial flexibility in the substance of some of the questions and in the ways of seeking particular kinds of information. In all cases the focus of the survey was simultaneously conventional, in terms of an inquiry into labor and capital markets affecting firm technology choice, and unconventional in terms of, first, locating the source of imperfections in

those markets and second, and more to the point, in terms of providing insights at the engineering or process level and in seeking to uncover meaningful differences in entrepreneurial capacity and information channels.

Baily's study of Colombian industry may be characterized as an attempt to break out of the traditional boundaries to some extent in all the dimensions previously emphasized. Taking the brick industry as an example, a major analytical facet of her research includes a confrontation with the engineering realities of brick production at the process level and an examination of the major market imperfections, focussing on the capital market, the labor market and the fuel market, all affecting technology choice at the individual entrepreneurial front. Moreover, an effort is made to examine the pecularities of access to information flows by different sizes and types of entrepreneurs.

In order to confront the aggregate information with engineering realities, sequentially ordered steps in brick manufacturing, i.e. excavation, preparation, forming, drying and firing, are identified within so-called "representative plants" to reduce the extent of actual variation, and a set of ten major technology choices in bricks (7 in men's shoes) is identified. These major production processes are arranged in a decreasing order of technological sophistication. The reasons why one is chosen over another across scales and across time, of course, lies at the heart of our inquiry.

Proceeding first with conventional analysis, the economic characteristics of the technology set are investigated in terms of their scale sensitivity, capital intensity and labor productivity dimensions.

An interesting innovation within this conventional analysis, though not yet carried to full fruition, is the attention paid to the intermediate fuel input. For example, in the drying process the two dominant engineering quality characteristics are natural drying and chamber drying. Since fuel costs, increasingly important as a consequence of the international energy crisis, are the crucial elements differentiating these particular alternatives, explicit introduction of this input as important relative to the use of labor and capital, and not neutral with respect to primary factor proportions, was verified qualitatively if not quantitatively by the questionnaire results. Not surprisingly, it is found that the relatively modern, sophisticated technology is usually associated with larger capital/output and labor ratios and higher labor productivity. In this inductive sense it is possible to examine the validity of the thesis of engineering determinism lending support to the "traditional" prediction that in exercising technology choice the profit maximizing entrepreneur is indeed price sensitive and, to the extent factor markets are distorted and are changing in terms of their relative price position over time, entrepreneurs respond to these signals.

However, when we try to explain the coexistence of large and small firms at any moment of time the historical dimension must be brought into the analysis. We have either a situation of disequilibrium or deviation from the perfect market approximation, or more likely a combination of these two factors. What we do observe is traced to the growth of firms of different vintages in the past. The underlying assumption is of a putty-to-clay type of production function so that it is mainly age or vintage which determines the technology choices visible in the cross-sectional sense at one

point in time, i.e. ex ante substitution is great but ex post substitution is severely limited . Thus, in case there is no technology change, factor prices and market demand conditions affect technology choice, as ordinary static equilibrium theory would predict. When there is technology change new firms will adopt the new technology which is more large, modern and sophisticated; old firms would like to grow into the new technology but are restricted by the nature of the putty to clay production function. A second major conclusion is that, even at a point in time when the putty is being formed in different-sized firms, it is imperfections in the factor markets, but not only with respect to the often referred to differential factor price distortions but also with respect to the unequal access to credit, which yields a wide range of technology choices. Market imperfections, of course, include the well known phenomenon of higher wages for larger firms producing a bias against employment as the size of the plant increases. But what is emphasized in the Colombian context is, on the one hand, the negative impact of overall variability of distortionary government policies; and, on the other, the importance of the "capital access function" which forces entrepreneurs into higher rates of interest as the need for credit rises, modified however by the preferential treatment accorded to the larger firms closer to the organized markets at all levels of additional borrowing. In other words, each entrepreneur has his own access function, i.e. the ability to gain access to credit markets depending partly on the size of the project involved but also (and more) on the characteristics of the entrepreneur in terms of the hierarchical nature of Colombian society. Thus the access functions for entrepreneurs may be more important in determining the optimum

size of firms than the production function.

Moving onto a more purely non-conventional arena Baily places a lot of emphasis on the imperfection in information channels with respect to technology options for different sizes of firms. These information channels include machinery suppliers, multinational corporations, official technical assistance, printed material, trading companies and personal, often ethnically oriented, contacts with foreign firms. Baily concludes that profit maximization incentives may be substantially dulled by such differentially powerful institutional forces. Individual firms, especially small ones, can only know a small part of the spectrum of opportunities available in nature as they look across scales and countries, and are unlikely to know what the total set looks like. Baily's interviews indicate that most entrepreneurs attach the greatest importance to direct contact with other firms but that the relative weight of different information channels will differ depending on the level of sophistication of the technology. The information about the existing international shelf requires expenditures on search, and experience, which are not usually available, especially to the smaller firms; as with small farmers, the uncertainty elements attaching to deviations from traditional practice are especially crucial for the small entrepreneur. It is therefore likely that the level of X inefficiency or sub-optimization is larger with respect to small and medium size firms, everything else being equal. What results is a limited diffusion of information with respect to variations in technology--concerning kiln and drying procedures in bricks, and factory lay-outs in shoes.

The Taiwan study by Fei comes to many similar conclusions. It presents a more explicit recognition of the ideas of transition growth by emphasizing the historical background which forces a cross section study of technology change such as this one to make certain heroic assumptions about the origins of the cross section of firms observed at any one moment of time. Here again we have a mixture of the traditional resources oriented approach and the less traditional type of approach emphasizing, first, market imperfections and then, moving on to a greater recognition of engineering realities as well as institutional and entrepreneurial characteristics which go beyond the normal boundaries of analysis in this field.

With respect to the traditional arena the Fei study of Taiwan provides a framework of reasoning about technology change which incorporates the coexistence of large and small firms at any moment of time, with the growth of such firms via a vintage capital formulation of the production function, making use of an aggregate representation of the traditional variety. In this way a framework is provided in which labor productivity, the capital/output ratio, the factor shares, capital per head, the rate of return to capital, employment and output in a multiple firm industry are determined. The purpose, of course, is to link these traditional variables to an understanding of the coexistence of large and small firms with different kinds of capital for any moment in time. It is, of course, obvious that such familiar indices constitute the basic information for most traditional aggregative analyses of technology choice and technology change.

It should be clear that, to explain aggregative behavior, some such

formal modeling is indispensable to all the effort under this project, both in terms of deductive reasoning as well as in terms of the initial framework for organizing data and providing a basis from which unconventional analysis can depart. The Fei/Taiwan approach is, in fact, complementary to the more informal analysis concerning the co-existence of large and small firms via a vintage capital approach in the Colombia study, testifying to a common conviction that in studying technology traditional indices must be used at the outset along with traditional analysis.

This is not to say that the new production function developed within the study is itself traditional. In fact, it represents a relatively new idea concerning a factor oriented scale sensitive production function motivated by the notion that scale may be traced to the size of the capital stock; once implemented empirically, it may have considerable importance. The point, rather, being made is that it lies within the area of discourse of conventional analysis in the tradition of the CES production function, for example. The basic notion here, intuitively, is that a larger capital stock, i.e. a larger kiln in the case of brick manufacturing, is more efficient because it can embody a multitude of scientific principles not feasible in a smaller, more primitive, kind of kiln. This intuitive idea leads Fei to the construction of a special type of neoclassical production function, scale sensitive with respect to capital, which hopefully can more aptly describe the engineering reality of some of these industries.

A difficulty shared by both the Taiwan and Colombia efforts was that the full implementation of the model, explicit in the case of Taiwan, was not possible because the quality of the data emerging from the

sample surveys turned out to be much inferior to what had been anticipated, for reasons already referred to. With census data notoriously bad and special sample surveys requiring high levels of human and financial inputs, as carried out here, not improving matters very much, our results with respect to the feasibility of statistical implementation of traditional models for the study of technology change represents a meaningful negative finding of the current research effort. That data in developing countries are poor is not a new discovery, but that the study of technology change at the firm level entails especially serious problems of a lack of recall and lack of trust by the interviewee has to be stressed even more than is customary. (We have parenthetically obtained what appear to be good micro data for a number of points in the case of the Mexican industrial census and are trying to implement the model presented by Fei with the help of these data.)

Taiwan represents a successful labor surplus developing country in our sample, one which at the time of this survey, according to other independent analysis[1], has already passed the turning point between the dualistic labor surplus and the neo-classical labor shortage growth phases. Accordingly, Fei downplays the importance of market

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[1] J.C.H. Fei and G. Ranis, "A Model of Growth and Employment in the Open Dualistic Economy: The Cases of Korea and Taiwan," Journal of Development Studies, January, 1975.

imperfections, i.e. distortions in labor and capital markets, in terms of their impact on technology choice. Instead, he moves into an area of non-traditional analysis which we have identified as focussing on entrepreneurial capacities,which still differentiates the Taiwanese entrepreneur from his mature economy counterpart in terms of the importance of matters beyond relative prices on profit maximization. Entrepreneurs need to be differentiated in terms of certain quality dimensions, experience, education etc. It is possible to talk about the growth of entrepreneurship and the quality of entrepreneurial decisions only via some classification of this kind. In fact, the growth of entrepreneurship is synonymous with the growth of innovative capacities in a society during its transition process.

Both Fei and Baily in a sense classify entrepreneurial or innovative capacity as proxied by the acceptance of and use of various sources of technological information. In the case of the Taiwan study the information is classified into that generated internally within the firm and that absorbed from abroad, with a number of subcategories within each source. The questionnaire in addition seeks some illumination of the motivation in terms of alternative technology choices and alternative instruments such as the purchase of new machines, and the improvement of labor skills to achieve alternative ends, i.e. the improvement of quality, market expansion etc. Information of this type which really lies beyond the traditional profit maximization analysis was obtained through questions focussed on entrepreneurial attitudes based on our questionnaire returns, which were perhaps richer,even though more

qualitative, than the narrowly economic data. Such a method was employed in both the Taiwan and Colombia studies.

The attitude surveys permit Fei to conclude that the entrepreneur in Taiwan, unlike his counterpart in an industrially advanced country, is likely to be more technology oriented, i.e. his experience is likely to be more important than his formal education. It turns out, moreover, that activities undertaken within the firm seem more important than those resulting from activities outside the firm. For the medium and small-scale entrepreneurial class collective activities are likely to be more important than for the large-scale entrepreneur, e.g. fairs, information provided by the government, etc. Not surprisingly, technology transmitted from abroad is likely to be more important for the larger firms, where trade is also a more important carrier of technology. While larger entrepreneurs are thus more technologically and quality of product conscious than medium and small scale entrepreneurs, the latter are likely to be more cost conscious.

Entrepreneurial aspirations, their intermediate goals and the sub-optimization routines to which they address themselves may be much more important in the context of a developing economy. While the fullest utilization of resources may be most important in the initial phases of transition, requiring concentration on cost consciousness, an entrepreneurial capacity defined more broadly is likely to become more important later on, including focussing on ideas generated outside the firm and increasingly related to trade and other connections with the rest of the world, as the transition process nears completion. In

other words, as long as the labor surplus condition persists in the typical LDC case the cost conscious entrepreneur has an important role to play, and improvements in the overall economic environment are needed in terms of the diminution of the distortions referred to. As the commercialization point ending labor surplus is approached entrepreneurs become more technology conscious, as in the Taiwan case.

The Cardwell analysis of the shoe and textile industries in Brazil once again presents a reasonable combination of traditional and non-traditional analysis in the sense used here. The main focus of the effort is to analyze the relationships among size, efficiency and profitability across different firms within these two industries. Once again a production function at the aggregative level is used to investigate the importance of economies of scale along traditional lines. Cardwell uses a rather interesting analytical scheme to classify firms within an industry empirically according to their size, efficiency and profitability. The efficiency criterion in particular represents something of a value judgement in the sense that a firm's degree of efficiency varies with its wasteful or unwasteful use of scarce resources from a private calculus point of view. The contrast between efficiency and profitability is really a contrast between social and private points of view arising from the existence of market imperfections.

The relatedness among the three schemes of classification is then examined with the help of multiple discriminant analysis in which technology indices and financial indices permit measurement along size, efficiency and profitability dimensions. The purpose here

is clearly not to come up with a behavioristic theory explaining the relationship among these indices in a purely theoretical fashion. Instead, the application of a pre-theoretical technique, such as multiple discriminant analysis, permits Cardwell to ask the following question: is the difference between a small and medium size firm primarily associated with technological factors as measured by the technology indices or with the financial factors as measured by the financial indices? The response to this question should be able to throw light on the bottleneck factor standing in the way of a rational expansion of the size of firms, i.e. as to whether what is blocking growth of the small firm relative to the medium firm, or of the medium relative to the large firm, are financial or technological factors. Cardwell's findings are that the technological limitations are not severe in nature but that the financial limitations in terms of unequal access and distortions are important. Her analysis permits us to conclude that differences in technology indices distinguish small and unprofitable firms from the rest, but that differences in the financial indices distinguish large firms from the rest. Overall the financial index is clearly more useful than the technological one in clustering firms by size.

The Cardwell results do not support the existence of a simple relationship between size and/or capital intensity, on the one hand, and efficiency or profitability, on the other. Her analysis of the men's shoe industry, for example, agrees with our findings elsewhere[1] that the

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[1] G. Ranis, Industrial Efficiency and Economic Growth: A Case Study of Karachi, Monographs in the Economics of Development, Pakistan Institute of Development Economics, No. 5, April 1961.

medium size is more labor intensive and more efficient, but the findings for textiles are somewhat deviant,with larger firms here found to be more efficient than either the medium or small scale.

Using standard production function estimation Cardwell found that neither industry under observation exhibited economies of scale; in fact, the smaller firms showed diseconomies in production as measured by sales. The advantages of large firms are partly based on natural economies of scale and partly on the benefits of market distortions in their favor. While industry situations differ as between shoes and textiles it seems clear that the more competitive environment would stimulate more labor intensive profitable firms in both cases. As in the Baily research on Colombia,segmented capital markets are viewed as the major cause of distortions. A more perfect credit market, it is emphasized, however, does not mean the same interest rate for all firms but the admission of differentials by risk, permitting the pooling of risk for smaller firms through institutional changes,but avoidance of monopoly or monopsony power in credit markets.

A recurring theme in all the studies thus resides in the effort to understand the differences in technology choice as they relate to the size of firms within these industries. While size is measured differently in some of the studies, the same concern is evident in all, i.e. how important is the scale of operations in determining the type of technology used. Secondly, except in the case of the Taiwan study, there is an effort made to determine the extent to which size is a proxy for unequal

market power and/or the results of operating in a different market environment as between large, medium and small scale firms. It is interesting that in the Taiwan case,by the mid 70's closer to a neo-classical model, firm size is more nearly determined by technological factors as a function of the vintage capital accumulated over time. Older firms would thus be smaller, more labor intensive and utilize older techniques; newer firms would be larger, more capital intensive and utilize more modern techniques. Characteristics of the entrepreneur would also be correlated with the size of the firm, with entrepreneurs in large firms more technology oriented, those in small and medium firms still more cost conscious, in keeping with their more labor intensive bias. For the developing countries at present still further away from a neo-classical situation we find, on the other hand, a lower correlation between size and technology and much more attention paid to the whole range of market imperfections in creating gaps between social and private profitability. Marketing and financial matters are much more important than the strict technological dimension in these cases.

All the studies take a great step forward in placing much more attention than conventionally on the weakness of the view that contemporary LDC's have before them the whole shelf of technology vintages across countries from which to make their choice. It is recognized, first of all, that the cost of search for technological information may be high and yield varying degrees of success. Secondly the entrepreneur may not feel the cost is warranted in terms of his own behavior pattern which may yield much more to sub optimization routines or forms of

satisficing behavior depending on his own capacity. A third problem, focussed on at least in the Colombia and Brazil studies, is that constantly changing conditions in the domestic market tend to lessen the value of such information and the chances of approaching optimization in general. Thus especially medium and small industry may have the same kind of aversion to new technology as a function of risk aversion as you find in agriculture in developing countries.

Finally, the work by Ranis and Saxonhouse focusses attention on the relationship between technology choice and various dimensions of quality both on the intermediate input, i.e. raw cotton, and on the output side, i.e. yarn count. The purpose here, within the traditional arena of conventional analysis, is to probe more deeply into the adaptive goods dimension of technological choice. In the same study the dynamics of technology change are explored in the context of the importation of U.K. spinning machinery into Japan during the late 19th century, the adaptation of this machinery and the diffusion of such technology changes throughout the industry. The contrast between the Japanese and Indian cotton textile industries is used to advantage in this context.

This effort is unconventional in two respects, one in going beyond the customary assumption that the limits of technological flexibility are exhausted by comparing process or technique for a given quality good when, in fact, most real world technology change is in the form of product differentiation. Secondly, it is unconventional in trying to

explain choices made over time in the 19th century Japanese industry by delving into the interplay between international information and machinery suppliers dimensions, the role of trade associations, and differential domestic institutional environments as between India and Japan, for example.

Two waves of labor using innovations, adopted in Japanese spinning but only gradually accepted in India during the late 19th century, are analyzed in terms of the differences in organizational features within the two industries. These differences had less to do with the extent of the overall protection and relative factor price distortions than with the relative strength of the competitive pressures, the functioning of the Japan Cotton Spinners' Association and the effects of the Indian Managing Agency system. The adaptation of Japanese imported technology, moreover, via such conventional indigenous innovational responses as the resort to more double shifting and the fuller use of the capital stock via the reduction of down-time and the more intensive maintenance of machines is quantitatively analyzed. But the study also proceeds with the less conventional notion of exploring the trade offs among various attributes of the cotton textile industry's output in terms of the absorptive capacity for the primary factor input in surplus supply. The two applications of the appropriate goods concept indicate that if relative commodity prices can be made to reflect more accurately the attribute bundle consumer choice decisions can be rendered more efficient in terms of the avoidance of irrelevant or even undesirable dimensions of quality, and at the same time the more efficient use of the economy's endowment

promoted.

The study, in other words, emphasizes the importance of domestic adaptations on top of new imported technology variants and indicates that the straightjacket of fixed proportions is inapplicable not only in terms of the existence of alternative technologies for a strictly defined product but also in terms of the important role of substitutability among production technologies once the implausible assumption of a perfectly standardized intermediate input and output quality mix is lifted.

An additional dimension of the study attempts to shed some new light on contemporary LDC labor markets by examining the impact of the paternalistic structure of the 19th century Japanese cotton textile industry experience from the point of view of individual worker characteristics and preferences as well as the effects on firms' recruitment techniques and technology choices. Rather surprisingly, in terms of commonly held beliefs, the textile industry labor force was mainly concerned with levels of direct renumeration and showed little job attachment in response to the paternalistic features offered. The high turnover, unskilled labor force of Japan thus proved highly efficient from the profit maximizing perspective of firm management.

Section III: Conclusions For Policy

Without attempting in each case to identify the particular study on which it is based and in full recognition of differences in precise

focus, methodology and, on occasion, even findings, this section attempts to distil what appear to be the main overall conclusions emerging from the project. These are, it needs to be emphasized once again, personal conclusions not necessarily shared by my project collaborators, based on this observer's assessment of what has emerged from our research in the broader light of the current state of our knowledge in this field.

First, and perhaps most important, is the recognition that the traditional emphasis on factor price distortions in explaining technology choices at the firm level which appear to be socially inappropriate is a necessary but not sufficient condition for understanding and action. It is necessary in the sense that the studies confirm entrepreneurial sensitivity to such signals, but insufficient in that government policies aimed exclusively at the reduction of interest rate subsidies, of artificially high real wages and overvalued exchange rates, can not be expected, by themselves, to have a corrective effect. The studies, rather, emphasize the possibility that the observed divergence in technology choice across firms may be due, at least, in part, to such traditional factors as economies of scale possibly combined with a vintage view of capital which does not permit everyone to adjust to the optimal technique at each point in time. To the extent such economies of scale are related to the raw material purchasing and product marketing ends of the production process, consideration should be given to the formation of trading companies and/or trade associations exclusively serving the smaller, medium sized companies--thus avoiding the customary large firm domination pattern,

permitting the coordination of inter-firm model offerings, and making larger production runs possible, e.g. in shoe manufacturing.

With respect to the physical production process itself, to the extent the economies of scale, putty-to-clay view of a disequilibrium industrial real world is accurate, relatively little can be done about it. However, when the same phenomenon is combined with, or even replaced by, the inequality of access in capital markets--a finding emphasized in all but the Taiwan study--the potential for corrective government action is clear. Thorough-going reform of the capital market seems to be of the highest priority. It should, moreover, be emphasized that this policy conclusion calls for more than the reduction of one crucial factor price distortion, but includes the likelihood that new public sector institutional construction or its facilitation by the private sector, may be required to try to equalize the access to capital of different-sized entrepreneurs. Otherwise the expected diffusion of "best practice" through the industry will be delayed and incomplete.

Also in this so-called hybrid area between conventional and non-conventional analysis we found, especially in the Brazil and Japan/India cases, that the extent of overall competitive pressures on the firm's output markets is of crucial importance. To the extent firms are enjoying unearned profits accruing from government protection, assured market shares and other sources of monopoly rents, we cannot expect them to engage in a very assiduous search for more appropriate existing techniques, or in R & D to find new ones. It is by now a well established fact, but

not any less true as a consequence, that government actions in the general direction of a more workably competitive environment for the industrial sector will be of great help in achieving more endowment-sensitive technology choices. The absolute protection of Colombian shoe manufacturing and the Managing Agency system in Indian textiles represent additional cases in point.

Another related conclusion, most strongly emphasized by Baily, is the impact of the degree of policy uncertainty in dulling the firm's profit maximization incentives. A strong case is made here for the superiority of a stable if mediocre set of government policies as against a stop/go widely fluctuating set which is superior on average.

But perhaps the more interesting and novel policy conclusions of our work result, not surprisingly, from the less conventional part of our analysis. These include placing a spotlight on the quality and quantity of information flows, on the one hand, and on the entrepreneurial capacity at the receiving end, on the other.

Turning first to information flows, it is clear that the inequality of access to technology information may be a major source of differential and non-optimal behavior. To the extent that government policy can increase the domain of non-appropriability (or "visibility") of technology relative to that of appropriability (or "invisibility"), for example, via a revision of often very lax technology transfer and patent legislation, the diffusion of new technology across firms can be substantially speeded up. When economies of scale in information channels are important,

as they often are, once again the encouragement of trading companies or of trade associations, on the Japan Cotton Spinner's Association model, should be considered. Public sector action to diminish the importance of special exclusive relationships between large domestic companies and foreign companies including machinery suppliers may also take the form of encouraging appropriate technology oriented R & D cum information gathering institutes on a careful and selective basis--with such institutes having to increasingly "pay their own way" by means of private sector contracts.

A modest institutional capacity of this kind would also be most helpful in transferring the important appropriate goods dimension of our findings into the actionable arena. Most developing economies already have the beginnings of some sort of science and technology institutional network--on which a substantial volume of resources gets expended regularly. Most of these institutions, however, have to date shown a minimal interest in the area of appropriate goods and/or appropriate technologies but rather spend their energies on break-through technologies and frontier science-related activities. Urging the redeployment of these resources in the direction of the diffusion of information, even as between different regions of the same country, concerning the feasibility of alternative attribute combinations yielding alternative product price possibilities,could be of great value. Outside funds to help stimulate such a redirection of the domestic effort--both in pure information dissemination and the usually needed and closely

allied R & D and technical assistance activity--could be of substantial catalytic value. Given the relative size of the rural sector of most contemporary developing countries the scope for more appropriate goods and/or technologies in expanding domestic markets is undoubtedly of much greater quantitative importance than the traditional emphasis on the traded goods sector. But both blades of an employment and equity oriented growth strategy stand to derive substantial benefits from more attention to institutional innovation in this area.

But when all is said and done, entrepreneurs themselves undoubtedly represent the principal means of technological transfer as well as local adaptation and diffusion. Thus their motivation and the instruments at their disposal constitute the most important dimensions which can be affected by policy action.

Since the technical capacity of entrepreneurs is apparently acquired mainly through informal educational channels of the "learning by doing" variety, the most reliable way to enhance this critical skill is to minimize government constraints on entry and permit the widest possible active participation. While such policies will make the largest contribution to the enhancement of technological capacity, smaller and medium sized firms would also benefit from such related cooperative activities as trade associations, fairs etc. While large firms seem to be more quality of product oriented it is the medium and smaller firms whose relatively greater concern with cost reduction renders them more interested in labor-using innovations and adaptations.