CHOICE OF TECHNOLOGY IN INDUSTRY

THE ECONOMICS OF GRAIN-MILLING IN TANZANIA

M.S.D. BAGACHWA

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Abstract

It is not uncommon to find many production units in low-income, labour-abundant, capital-scarce economies such as Tanzania employing sophisticated and capital-intensive production techniques. In such circumstances, a problem of technology choice exists in the sense that the technologies in use, and more often the products being produced, are not compatible with the resource endowment of the economy and the income levels of the majority of the population.

This book evaluates the relative performance of alternative grain-milling techniques in Tanzania to identify appropriate ones and explain why some firms select inappropriate techniques and products. The consequences of technology choice are then discussed within the context of employment creation, output expansion, surplus generation, skill formation, and overall resource use.

Résumé

Il est fréquent de trouver, dans des pays comme la Tanzanie où les revenus sont faibles, la main d'oeuvre abondante et les capitaux rares, des unités de production qui emploient des techniques perfectionnées exigeant de gros investissements. Cela illustre un problème de choix technologique en ce sens que les techniques employées et plus souvent les produits obtenus ne sont compatibles ni avec les ressources de l'économie ni avec le niveau de revenu de la majorité de la population.

L'auteur évalue le rendement relatif de diverses autres techniques de mouture des grains de céréales en Tanzanie pour déterminer celles qui seraient appropriées et expliquer pourquoi certaines firmes choisissent des techniques et des produits non indiqués. Il aborde ensuite les conséquences du choix technologique dans le contexte de la création d'emplois, de l'élargissement de la production finale, de la production d'un surplus, du perfectionnement de la main d'oeuvre et de l'utilisation globale des ressources.

Resumen

En economías de bajos ingresos, abundantes en mano de obra y con escasez de capital como la de Tanzania, no es raro encontrar numerosas unidades de producción que emplean técnicas de producción complejas y que requieren gran inversión de capital. En tales circunstancias, existe un problema de selección de tecnología ya que las tecnologías en uso, y más a menudo los productos que se producen, no son compatibles con los recursos disponibles en la economía y los niveles de ingreso de la mayoría de la población.

Este libro evalúa el rendimiento relativo de técnicas alternativas de molturación de granos en Tanzania con el fin de identificar las que son apropiadas y explicar por qué algunas empresas seleccionan técnicas y productos inadecuados. Las consecuencias de la selección de tecnología se debaten en el contexto de la creación de empleos, expansión de la producción, generación de excedentes, formación de personal calificado y utilización general de recursos.

Acknowledgments

During the course of writing this book, the list of persons to whom I am indebted for guidance and assistance has been growing. Unfortunately, space does not allow me to name all of them. I wish, therefore, to express my sincere thanks and appreciation to all those who extended their valuable assistance to me.

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The responsibility for what is written in this book, however, remains mine.

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Foreword

Since 1982, the International Development Research Centre (IDRC) has been providing support to studies on technology policy in eastern and southern Africa under the umbrella of what has come to be known as the "Eastern African Technology Policy Studies" (EATPS) network. The network aims to generate information usable in designing and implementing future policy or in assessing the impact of existing policy. This book is a result of a study carried out by a member of that network.

Dr Bagachwa examined the grain-milling industry in Tanzania, paying special attention to empirical evidence regarding the choice of technique in that industry. This book presents his findings, interpretations, and conclusions. It integrates many strands of arguments and analyses a large body of data. As a result, its conclusions carry much persuasive force.

From some of those conclusions emerge specific policy recommendations. These are currently of special importance in sub-Saharan Africa. Implicit in the region's ongoing attempts at industrial rehabilitation are choices that they address. Those choices, as Dr Bagachwa argues, need to be made explicit and the consequences of alternative choices to be examined and compared if rehabilitation is to avoid repeating errors of the past. Dr Bagachwa attempts to meet this need directly; it is hoped that decision-makers, especially in Tanzania, will accord his recommendations the attention they deserve.

There has already been praise for the organization and analysis that Dr Bagachwa has achieved in this book. The praise is richly deserved. I hope the book will serve as a model for further empirical work of the kind Dr Bagachwa carried out. I am especially pleased with its publication, as, I am sure, are all members of the EATPS network. However, I hope that researchers outside the network will find it equally of interest.

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Chapter One: Introduction

For the past decade and half, the possibilities for substitution among factors, or more explicitly the question of technological choice, has assumed an important role in the literature on economic development. Interest in the subject stems mainly from concern with providing employment to the growing labour force in the developing countries. In particular, disenchantment has been growing with the past industrial policies pursued in the developing countries. It is contended, with good reason, that the industrialization process in the developing countries has been characterized by two perverse tendencies: one, what Lipton (1977) has termed the "urban bias" and the other, what White (1978) has labeled as the "inappropriate factor proportions" or inappropriate production techniques and products.

The simultaneous development of these rather perverse tendencies has culminated in a number of socially undesirable side effects that are broadly expressed in mass migration into cities, high rates of urban unemployment, and increasing mass poverty. Unfortunately also, these obnoxious developments are taking place in countries where the welfare institutions of the state are virtually inoperative or non-existent. To counteract this "dualistic" tendency, then, investment must be directed into industrial processes that not only offer substantial employment opportunities, but also ensure that the benefits of industrialization do not by-pass most of the population in rural areas and small towns (Schumacher 1973).

It is from this concern with creating employment opportunities or workplaces that a number of institutions and individuals have joined forces to search for and support technologies that could facilitate the attainment of employment-intensive, redistributive, and basic-needs objectives. This search for appropriate technology (AT) has taken two directions: one theoretical and the other empirical. At the theoretical level, the focus has been on the criteria for selecting the AT. At the empirical level, the search has focused on whether choice of alternative techniques exists. The underlying hypothesis is that the greater the substitution possibilities, the greater will be the range of alternative technologies available on the shelf and, therefore, the greater the scope for investing in more labour-intensive processes that could reduce unemployment.

The question of whether meaningful technological choices exist in the developing countries is crucial for policy. If, on the one hand, technological rigidity prevails, then the question of technology choice becomes less significant and, for a given branch of industry, the major concern becomes one of industrial composition (Stewart and James 1982:2). On the other hand, the existence of a range of technological choices necessitates the need for a creative search for AT through a careful selection or alteration of factor proportions embodied either in new equipment or, as Winston (1979) suggests, in used equipment. A technology problem would exist, therefore, if the technologies in use in the developing countries are not compatible with the resource endowment and the needs of the majority of the population in these countries.

In the literature, there have been two extreme views concerning the debate on, and the search for, technological choice: one pessimistic and another optimistic. The pessimistic view holds that possibilities for factor substitution in the developing countries are practically nonexistent. This is because the nature of technological progress that takes place mainly in developed countries is capital biased. Consequently, because the developing countries import most of the technology, they can only choose from the existing capital-intensive alternatives. Growing capital intensity in the developing countries is, therefore, inevitable. In contrast, the optimistic view holds that efficient factor substitution is feasible in the developing countries. The growing capital intensity in industrial processes of the developing countries is attributed to distorted market prices of primary factors that convey the wrong signals to entrepreneurs.

What is the evidence and where does the debate stand? Chapter Two discusses the salient features of this debate and reviews some of the existing empirical studies on choice of technology and factor substitution. Clearly, the available evidence is inconclusive and does not admit to simpler propositions or generalizations. Factor substitution has been proven to exist in several processes but this does not rule out technological determinism in other processes.

The crux of the matter, as explained by Stewart (1987) and indeed shared by Fransman (1984), is that technology choice is far more complex than generally assumed. It is not only an issue involving decision-making units, with specified objectives selecting a particular technique from a shelf of technology subject to the state of technological knowledge and other economic-resource constraints, but also a decision about consumer preferences, the type and quality of the product to be produced, potential markets, government, and the whole socioeconomic framework. In addition, a decision on technology choice reflects certain behavioural aspects of technology suppliers, foreign aid donors, and the time preferences of the society in question. Consequently, the analysis of technology choice and the implied solutions cannot be really meaningful without commensurate consideration of the whole set of these complex forces. In other words, the question of technology choice remains largely an empirical issue.

This study is, therefore, a contribution to this debate. Despite the current shift in focus in the study of developing countries' technology toward technological change (see, for example, Lall (1982), Stewart and James (1982), and Fransman (1984), who explain the source and direction of this shift), in the case of Tanzania, the question of technology choice is still worth investigating. After all, technology choice has always been a seedbed for technological progress. Moreover, in the case of Tanzania, the absence of detailed and systematic analyses on the subject, the implicit recognition of this problem by planners, and the emphasis put on the issue by policymakers make such a study on choice of technology more compelling. This is particularly so for a strategic industry such as grain-milling, which is the focus of this investigation.

Furthermore, as I show in Chapter Two, the few studies that have been undertaken in Tanzania have focused on sectoral aggregates; however, this may mask differences in activity mix and product characteristics. This is why more disaggregated or firm-level information has been chosen. There is yet another gap:

the fact that the existing studies have not analyzed options for technological choice among small firms. The emphasis has always been put on large-scale firms, the implicit assumption being that different plant sizes employ technologies that are about equally efficient throughout a range of output. However, economies of scale may limit technological choice in some cases. Moreover, small and large firms may employ different technologies and may face different technological constraints (Kim 1984).

This is precisely why the need to analyze technological choices and constraints among both small and large mills is emphasized in Chapter Three. These aspects, however, constitute a part of the general objectives of this study. The general objectives of the study are also described in Chapter Three and centre on analyzing the existence of technological alternatives and the factors that determine technological choices within the grain-milling industry. To obtain the necessary information, a number of operating grain mills in the country were visited and data-collection methodology and measurement problems are described briefly in this chapter. Chapter Three ends with a simple neoclassical static model that is developed to provide a framework within which the constraints on the miller's choice of technology can effectively be analyzed.

Typically, however, a model is a simplification of reality. It provides only the skeletal aspects of the structure. To add some flesh to the model, the issue of technology choice must be positioned within historical and institutional contexts. This is done in Chapter Four where the evolution of the grain-milling industry in Tanzania is traced. A careful analysis of the institutional framework reveals that the way that milling firms are organized, the type of markets they serve, the overall policy environment within which they operate, and the type of product they produce are important factors in determining the type of technologies in use.

Technologies, however, are not only designed to produce products that satisfy a particular pattern of demand, but also developed in conformity with a particular set of input requirements. Thus, the extent and effectiveness with which a particular technology uses economic resources constitute an important consideration in the process of making decisions on technology choice. Bearing in mind that the overriding goal for acquiring technology in the developing country is the desire to build up an indigenous capability — not only to produce products, but also to innovate and sustain innovation in a local context — then one way of assessing the appropriateness of technology is the extent and effectiveness with which it uses local resources. Chapter Five, therefore, examines the suitability and effectiveness of different milling technologies in six areas:

- potential for employment generation;
- economy in the use of capital;
- energy conservation;
- capacity utilization;
- linkage effects; and
- surplus generation.

Caution is necessary, however, when interpreting these results. From the point of view of consumers, custom- and merchant-mill products differ in both quality and service characteristics. Ideally, substitution possibilities between small and large firms should be compared when the final product is a close — in theory a perfect — substitute. However, even after a careful comparison is made, it turns out that firms operating at lower scales of output score well in terms of employment generation, better use of capital, and in some cases generating a surplus.

As mentioned earlier, in the existing studies on choice of technology, the question of economies of scale is rarely addressed. In Chapter Six, evidence on returns to scale is presented. Additionally, the chapter presents empirical evidence on the elasticity of substitution. The absence of significant economies is consistent with Pack's (1982) belief that, on the whole, there is no strong tendency favouring capital-intensive technology as output levels increase. It is also found that, although the core milling subprocess is to a large extent technologically determined, the peripheral subprocesses of materials handling, feeding, and packing offer themselves readily to the substitution of manual for mechanical operations. The question of different production functions is not statistically proven, however. We can only rely on the previous qualitative analyses to assert that custom and merchant mills face different production functions.

Finally, the study concludes by indicating, in Chapter Seven, major areas of policy concern. I also point out that the results would have been more refined if some of the dynamic aspects that mould decisions on technological choice and that are manifest in the form of technological progress could have been considered.

Chapter Two: Choice of Technology — A Conceptual Framework

This chapter examines various theoretical and empirical approaches to the study of technological choice. It should provide a theoretical background to this study on choice of technology in grain-milling industry in Tanzania. The chapter is divided into five sections.

Section one defines concepts. Section two reviews briefly the major development theories on the study of technological choice and their policy implications to the economies of the developing countries. These include the neoclassical theory of variable factor proportions, the factor rigidity theory, and the approach articulated by the appropriate-technology school of thought. A discussion on some of the application of these theories follows in sections three and four to provide an empirical illumination. Section five reflects on two salient issues emerging out of this discussion. These relate to the conception of technology in a broader context and the complexity surrounding technology selection mechanism with particular reference to the grain-milling industry in Tanzania. This section ends by suggesting testable hypotheses that emerge from the discussion.

Basic concepts

The concept of technology derives from two Greek words "techne" and "logos" meaning technique and knowledge, respectively. In this sense, technology may literally be interpreted to mean "knowledge about techniques." In this study, however, I have adopted Stewart's (1977) much broader definition of technology that incorporates both the hardware and software components of production. The hardware component relates to knowledge about machines, products, and methods of production. The software component relates to skills and knowledge about procedures necessary for designing, producing, acquiring, or marketing a product or service, or managing relevant practical tasks. When taken in this context, technology as knowledge goes beyond the confines of production of goods and services. It also extends to the distribution and consumption functions and the manner in which these functions are organized. Consequently, in this study, although the question of technological choice is posed in a manner that reflects more explicitly the hardware aspects of milling technology (i.e., alternative milling equipment), it should be remembered that the software aspects are at all times being implicitly assumed, because the two are closely related.

Although a broad consensus exists in interpreting technology as a system of knowledge required to manage the methods of production, distribution, and consumption, a distinction is sometimes made between concepts of "technology" and "technique." Some authors, such as Alange (1987), Ishikawa (1972), and Stewart (1977), define technique as a subset of technology. They differ, however, on the elements of the subset. Alange, for example, defines technique purely as the hardware of production — machine processes. Ishikawa and Stewart view technique as part of knowledge pertaining to individual components of technology as a system. To quote Stewart (1977:1–2),

> Technology consists of a series of techniques.... Each technique is associated with a set of characteristics. These characteristics include the nature of the product, the resource use — of machinery, skilled and unskilled personnel, management, materials and other inputs — the scale of production, the complementary products and services involved etc.

Although such a distinction is useful in distinguishing the particular characteristics of the subset from the overall characteristics of the "whole" set, it raises one important conceptual problem. That is, the dividing line between technology as a set and technique as a subset is hard to identify and can only be drawn with some elements of arbitrariness (Skarstein and Wangwe 1986). For example, the degerming process in maize milling may be viewed as a subset of the maize-milling technology, which in turn may be viewed as the subset of grain-milling technology. Clearly, the distinction between the "part" and the "whole" depends, in this case, on the level of analysis that one would like to undertake. Thus, partly because of this problem and partly because of the existence of vertical and horizontal links between the set and the subset (i.e., existence of interdependence in the production process), I use the two concepts of "technology" and "technique" interchangeably here.

Given the thrust of many studies on the nature of developing countries' technology (outlined in Chapter One), the concept of "appropriate technology" (AT) has become central to the analysis of technology choice. Being a relative concept, AT has meant different things to different people.

Stewart has, however, conveniently grouped the many and diverse definitions of AT into two main contrasting views. The first view derives from welfare economics and regards AT as a set of techniques that can optimize social welfare when factor prices are shadow priced. The second approach involves the specification of a certain set of technological characteristics that are considered ideal in a given socioeconomic environment (Stewart 1987:2–3). However, as Stewart rightly points out, although neither of the two views is perfect, the specific-characteristics approach offers a better perspective than one based on social welfare because, by recognizing that all techniques are in a sense inappropriate, the former approach sets the basis for a new spurt of action in further research and search for AT.

It is in this context that I have largely adopted the specific-characteristics approach to define AT in the grain-milling industry. According to Tanzania's long-term basic industrial strategy (BIS) (1975–95), the "basic industries — those which use domestic resources to produce essential commodities for consumers or domestic industries will receive priority" (URT 1976:17). Working from the BIS objectives, which stress, inter alia, the need to achieve structural change, self-reliance, and basic-needs objectives, it is useful to define AT in terms of the extent and effectiveness to which techniques:

- Use locally available resources, particularly labour,

- Economize on scarce resources, especially capital and foreign exchange,
- Ensure full capacity utilization,
- Generate surplus,
- Foster linkages,
- Minimize costs, and
- Produce appropriate products.

Defined this way, AT encompasses appropriate techniques and products, i.e., products with characteristics best suited to meeting the basic needs of low-income consumers and producers (Stewart 1987). AT is, therefore, resource- and country-specific. It also changes over time as resources and society's needs change.

The logic underlying the choice of this set of AT characteristics crucially hinges on the (perhaps controversial) assumption that Tanzania's broad development policies reflect the economy's societal, cultural, socioeconomic, political, and technological needs and, hence, constitute sensible norms against which performance can be judged. This approach has also an appeal for pragmatism in the sense that the implied AT solution is more likely to be acceptable to Tanzanian policymakers. Ambiguity may still arise, however, if conflict occurs among the unweighted AT characteristics. Furthermore, the solution (AT) arrived at under this approach could still be technically inefficient. In principle, AT must be efficient if output is not to be sacrificed. This problem is resolved by resorting to partial factor productivity indices and by estimating benefit–cost ratios for alternative techniques at both market and social prices.

The problem of "choice of technology" may then be viewed as revolving around three interrelated aspects: the economic decision-making units and their objectives, the set of technologies available on the shelf, and a series of resource constraints (Ishikawa 1972; Stewart 1977). This study focuses on three main economic decision-making units, that is, household mills, small-scale private mills, and large-scale public mills. Decision-makers in each economic unit have objectives that they strive to accomplish. These objectives may be common or they may vary across the economic units and they may also be accomplished in a number of alternative ways. These consist of a spectrum of all known technologies available in Tanzania. Such technologies may have been imported or manufactured locally. Consequently, decision-makers have to design a choice criterion. As I explain in Chapter Three, the criterion assumed in this study is that of optimization.

Once equipped with the choice criterion and having the objectives of a certain economic unit in mind, a decision-maker delineates an objective function. The objective function consists of the dependent variable representing the object of maximization or minimization and a set of choice variables whose magnitudes the economic unit in question seeks to optimize.

The quest for the best (optimum) technique is, however, constrained by the quality and quantity of resources available, i.e., various input requirements, infrastructural facilities, environmental condition, markets, government policies, etc. Thus, the essence of "choice of technology" is to find the set of values of the choice variables (techniques) that will yield the desired extreme of the objective function subject to resource constraints.

Theoretical approaches to choice of technology

Most analytical models used in most empirical research on technology choice have been derived from the economic theory of production. Traditionally, production technology is conceived as consisting of alternative methods for transforming inputs into outputs. An analysis of the behaviour of this transformation process could, therefore, provide some insights into the technical constraints that limit the range of productive process of an individual firm. It is not surprising, therefore, that most models on choice of technology crucially hinge on the assumption about the possibility of ex-ante and ex-post variations between inputs and input–output ratios. It is also on this basis that Phelps (1963), identified three model types: putty–putty, putty–clay, and clay–clay models.

In the typical two-factor (labour–capital) analogy case, the putty–putty model treats capital as putty, which can be continuously reshaped to accommodate any supply of labour at various levels of output. Both ex-ante and ex-post variations between inputs and input–output ratios are thus assumed. There are, thus, no unique input–output ratios associated with any given technology. In this case, it is empirically difficult to ascertain the existence or otherwise of technology choice in terms of unique input–output ratios. Putty–clay models, on the other hand, assume ex-ante substitution between inputs and rigid factor proportions and capacity ex-post (Johansen 1959, 1972; Salter 1960): only new capital is putty. Before new investment is made, there is a shelf of technologies to choose from. However, once investment is made, rigid factor proportions and capacity prevail. The clay–clay model assumes both ex-ante and ex-post fixed-factor proportions implying nonexistence of technology choice.

It is basically these models that have provided the analytical framework for most empirical studies on technological choice. The neoclassical production-function analysis with its smooth factor-substitution possibilities and multiple technological choices neatly corresponds to the ex-ante production function in the putty–clay model. The view advanced by factor-rigidity theorists, that technology choice does not exist in the developing countries clearly, stems from the assumption of fixed factor proportions characterizing the clay–clay model. Finally, the approach articulated by the AT school of thought appears to provide a synthesis of the previous models. Specific features for each of these models follow.

Neoclassical approach

The neoclassical analysis of technology choice is based on the model of pure and perfect competition. The basic analytical tool is the production function, which "expresses the relation between the maximum quantity of output and the inputs required to produce it, and the relation between the inputs themselves" (Brown 1966:9).

Within the neoclassical frame, a production function embodies an abstract technology. This technology determines, at any time, the input–output relations and the relations between inputs themselves. In particular, an abstract technology has four attributes. The first is the efficiency attribute, which determines the output that results from a given set of inputs. The second is technologically determined economies of scale, which describe the extent to which a proportionate change in inputs generates a proportionate change in output — Marshall (1922) distinguished between external economies that arise from the general development of industry and internal economies that depend on the organization and efficiency of management within the firm. The third is capital intensity, which denotes specific proportion of the quantity of capital to that of labour. Last is the elasticity of substitution, which indicates the ease with which capital is substituted for labour (Brown 1966).

Given the assumption of substitutability between capital and labour, the theory postulates that a given output may be produced by a variety of technologies, i.e., various combinations of capital and labour. In the neoclassical world, there are thus a near-infinite array of technologies for producing a given product.

Because different technologies can use different combinations of capital and labour, the neoclassical model of choice of technology boils down to choosing technologies of differing capital and labour intensities. Governing this choice are the relative prices of capital (rental charge) and labour (wage rate). A technology will be chosen if it maximizes profits in the competitive setting given the relative prices and substitutability between the primary inputs.

The neoclassical conception of technology choice is illustrated in Fig. 1. For expositional purposes, only two inputs — capital (K) and labour (L) — are assumed. The smooth convex isoquant IoIo reflects different efficient technologies that may be used to produce one unit of output. If pp′ is the relevant factor-price line, profits are maximized at A where the relative marginal productivity ratios are proportional to the wage–rental ratios. The resulting equilibrium of factor proportions at A define the optimum technology to be adopted.

The inappropriateness of a given technology is basically explained in terms of departures of factor prices from those corresponding to this theoretical optimum (Eckaus 1955). Thus, in Fig. 1, if pp′ captures the correct (shadow) prices, only

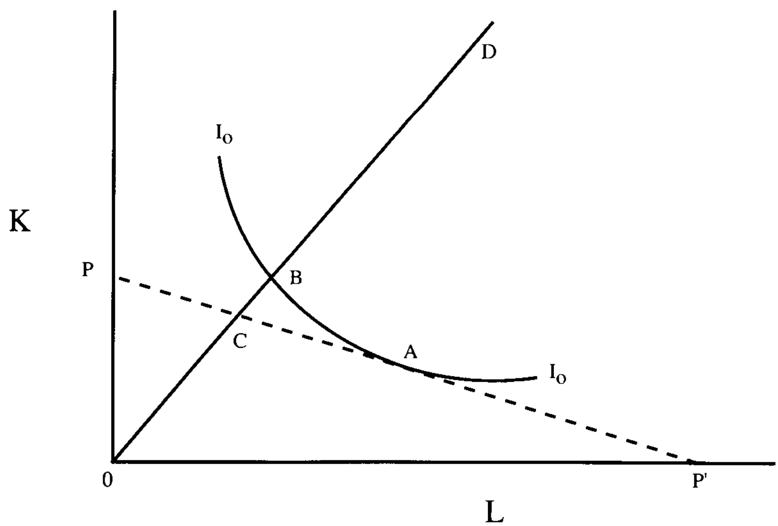

Fig. 1. Neoclassical choice of technique.

firm A is price efficient and hence uses an appropriate technology in the neoclassical sense. Firm B, although technically efficient, is price inefficient and is said to employ inappropriate technology. The actual prices at B misrepresent resource scarcities. As a result, this tends to bias entrepreneurial decisions in a socially suboptimal, capital-intensive direction. There may be several causes for this. Labour is plentiful but overpriced because of inordinate union pressure; capital is scarce but public policy (e.g., overvalued exchange rate, tax and credit subsidies, protective tariffs, etc.) underprices it so as to induce the motivation to invest.

The policy implications of the neoclassical model as far as the developing countries are concerned are mainly twofold. First, because the developing countries are endowed with plentiful labour (whose social cost is assumed to be low or zero) but have scarce capital, they are bound to face low wage–rental ratios. Such labour-abundant countries should, therefore, adopt labour-intensive technologies. To ensure that appropriate choices are made, criteria for such choices should stress the need for maximizing the benefits from the most scarce factor — capital — Sen (1957) presents an excellent survey on this. Polak (1943) and Buchanan (1945) have suggested maximizing the rate of turnover (i.e., the ratio of output to capital) as a criterion. Lewis (1954) and Meade (1961) have demonstrated that this criterion tends to favour labour-intensive technologies in the developing countries. Others have suggested the need to include, apart from capital, the opportunity cost of other factors of production — see, for instance, Chenery (1953) and Khan (1951) who coined the criterion of social marginal productivity.

The role of capital in production is further emphasized in the criterion of the per-capita reinvestment quotient suggested by Galenson and Leibenstein (1955), Dobb (1956), Kaldor (1978), and Sen (1968). These, however, approach the problem in a more dynamic setting and arrive at a different conclusion favouring the use of capital-intensive technologies in the developing countries. In particular, it is argued that, if the surplus per unit of capital invested is maximized, it would lead to higher rates of growth in the future. Additional employment, even under conditions of excess labour supply, implies extra purchasing power that necessitates more consumption and blocks investment expansion. Thus, given a sufficient period, the employment and output generated under the reinvestment criterion might overtake the stream of output generated under the rate of turnover criterion.

A crucial assumption behind this is that wages are always consumed by wage earners and profits are reinvested by capital owners. Capital-intensive technology would raise the share of capital of those who have high rates of savings and reinvestment rates. This will quicken the pace of capital accumulation and facilitate economic growth.

Although the reinvestment-rate criterion introduced a dynamic element in the analysis and, given the appropriate social rate of discount, can generate more meaningful comparisons, the approach has still the tone of the neoclassics in the sense that it revolves around the suboptimality of savings and investment and their response to different factor proportions.

The second neoclassical policy prescription is based on correction of distortions in market prices. If, as is assumed, firms in the developing countries respond neoclassically to factor prices, then distortions in market prices will lead to adopting inappropriate technology. To avoid this problem, national governments should pursue policies that ensure that market prices align with factor scarcities. Only then could firms be expected to make socially desirable choices.

Certain conceptual and analytical objections have been raised against the neoclassical model of technology choice. As is shown in the next section, factor-rigidity theorists are pessimistic about the existence of a wide range of technologies available for producing a given product. There is a large and growing body of debate on this issue that I examine later in more detail. However, it suffices to mention at this juncture that, even if, as revealed by most empirical studies, a range of feasible technological choice exists in the developing countries, the range "is clearly not infinite but confined to a few discrete techniques" (Stewart 1977:157).

Another limitation of the neoclassical analysis is its preoccupation with only two aspects of the technology package — capital–labour input combinations and their corresponding relative prices — and little systematic attention has been given to other institutional and technical aspects of the package, such as the nature of product, role of other material inputs, and other infrastructural requirements. The neoclassics also overlook other dynamic factors such as the importance of learning by doing (Arrow 1962; Bagchi 1978) and investor's expectations about possible future improvement of alternative techniques (Pasinetti 1981), all of which may influence technological choices.

Furthermore, the analysis is cast in a single hypothetical decision-maker: the profit-maximizing firm or industry. Even if a firm pursues cost minimization as a goal, however, it will definitely seek to optimize output per unit of all inputs and not simply output generated by labour and capital inputs alone. Moreover, different firms, even when producing a similar product, may have different objectives and may face different technological constraints, such as an uneven capacities to assimilate or "depackage" technology, uneven financial and technical constraints between small and large firms, and market size constraints. In terms of determinants of technology choice, the model focuses on factor prices, yet this is one of the manifold determinants.

Fixed-factor proportions approach

The fixed-factor proportions theory questions the plausibility of the neoclassical assumption of a near-infinite range of available technologies. This theory is based on the Leontief–Harrod–Dommar assumption of constant input coefficients. The assertion of the theory is that each product is producible only by a simple technology for which factor proportions are rigidly specified. Technological determinism thus prevails and there is only one efficient way to produce a given product. Selection of a particular product would, therefore, determine the type of technology to be used. Possibilities of factor substitution do not arise in this case.

The theory draws much of its support from the observation that almost all technological innovations take place in developed, high-wage and high-income countries. In such countries, the direction of technological change is toward labour-saving innovations — it is also assumed that the newer capital-intensive technologies supersede the older ones that become obsolete and thus the equipment embodying them ceases to be produced. The technology-transfer process in the developing countries is bound to exhibit this labour-saving bias. As a result, developing countries do not have efficient technology alternatives other than those with high capital–labour ratios found in developed countries. The efficient factor combination is considered to be fixed in the proportions found in developed countries (Eckaus 1955; White 1978).

To correct inappropriate factor proportions in the developing countries, this approach puts forward two basic solutions: changing the composition of output or modifying modern technology (through engineering and economic studies) to be more labour intensive. One way of changing product composition is through income distribution that adjusts supply to demand. Alternatively, a preferred product mix can be attained through administrative fiat.

Detailed empirical evidence on this issue is presented in the *General literature survey* section of this chapter. However, a casual inspection of "any less-developed country's industrial census which contains capital will reveal capital–labour ratios that are usually a third of those in the USA" — White (1978:31) lists supportive evidence on this but he also notes a few exceptions. This approach, however, highlights one of the major dependency relations found in the developing countries: that of technological dependence.

Appropriate technology approach

Another development in the literature is the AT approach. This combines some of the instruments of neoclassical theory with those of fixed-factor proportions theory. From the neoclassics, the AT approach borrows the notion that appropriateness of technology should imply convergence of factor use with factor availability in a given region. From the fixed-factor proportions theorists, the approach shares the view that most developing countries have no meaningful choice of technology because most equipment is built to suit factor availabilities in developed countries.

The major concern of this approach is the lack of technologies that are tailored and adapted to the conditions of the developing countries. A plethora of concepts and terms has subsequently been coined to describe the new technologies that do not exist or have fallen into disuse in the developing countries. For instance, Dickson (1974) promoted the use of "alternative technology"; Schumacher (1973) developed the concept of "intermediate technology"; UNEP (1975) came up with "environmentally sound appropriate technology." At times, the differences between these broadly synonymous terms becomes one of semantics. These terms are also of relative notions. For example, in most of Africa, the ox-plow may still be regarded as a good example of an intermediate technology as it stand between the traditional hand hoe and the modern tractor. In Middle East and Asia, however, ox-plows have been in use for centuries and are regarded as traditional technologies.

Unlike the neoclassical theorists, however, the AT approach prescribes the generation and use of "alternative" technologies instead of recommending static factor-price adjustments. As Schumacher (1973:174–175), one of the most ardent proponent of this approach, puts it, the main task of development is

> To bring into existence millions of new workplaces in the rural areas and small towns.... Modern industry as it has risen in developed countries cannot possibly fulfil this task ... it has risen in societies which are rich in capital and short of labour and therefore cannot possibly be appropriate for societies short of capital and rich in labour.

In one of the variants of this approach, the notion of dualism ranks high.

Economies of the developing countries are assumed to be characterized by two sectors — one traditional and the other modern. The traditional sector uses rudimentary and low-productivity technology whereas the modern (urban-based) sector employs capital-intensive and high-productivity technology that is almost a replica of that used in developed countries. The approach is then concerned with improvement and productivity of the work places in the traditional sector, on the one hand, and the modification of modern technology (by trying to reduce massive use of capital) in the modern urban sector, on the other. Schumacher (1973:169) uses a captivating example to illustrate this point.

> If we define the level of technology in terms of "equipment cost per workplace," we can call the indigenous technology of the typical developing country — symbolically speaking — a £1-technology, while that of the developed countries would be called a £1 000-technology.... If effective help is to be brought to those who need it most, a technology is required which would range in some intermediate position between the £1-technology and the £1 000-technology. Let us call it — again symbolically speaking — a £100-technology.... Such an intermediate technology would be immensely more productive than the indigenous technology (which is often in a condition of decay), but it would also be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry.

President Nyerere (as he then was) seems to echo the views of intermediateness in technology when he laments on two different occasions:

> We are using hoes. If two million farmers in Tanzania could jump from the hoe to the oxen plough, it would be a revolution. It would double our living standard, triple our product. This is the kind of thing China is doing [quoted in Smith 1971].

Later, he added (Nyerere 1977),

> The truth is that the agricultural results have been very disappointing. Modern methods have not spread quickly or widely, the majority of our traditional crops are still being grown by the same methods as our forefathers used.... People still think in terms of getting a tractor for their farms — even when they are small — rather than learning to use ox-ploughs.

According to this view, the immediate solution to the problem of inappropriate choice of technology in developing countries is to design and build demonstration-model technologies that are consistent with developing countries' factor endowment. White (1978) contends that this could be made possible through well-directed research and development and with improved methods of training workers. Some critics have observed, however, that such a solution is purely technical and is likely to be divorced from the real social and economic process of change at work (Stewart 1977:95–113). Others, like Bhagavan (1979), point out the lack of technomanagerial capabilities in planning, designing, and managing the new technologies. Moreover, the limited size of the market in the developing countries may entail higher costs of innovation and development in relation to available profits. Consequently, suppliers of technology, particularly the multinational corporations, may feel insecure in investing in such ventures.

The theoretical debate on approaches to the study of technology choice has, in turn, sparked off a series of empirical studies seeking to test the validity or otherwise of the advanced hypotheses. Before I summarize this evidence, it is important to bear in mind that each of the three approaches has its own theoretical cornerstone. It would be misleading to expect that empirical confirmation of one view would necessarily be used to reject the other. On the other hand, however, as the following existing empirical evidence indicates, the extreme views expressed by the neoclassics and factor-rigidity theorists can, in a way, be synthesized. Thus, in my opinion, the issue of technological choice should revolve more around *fixity of range* within the available technology shelf rather than on the extreme assumptions of either variable proportions or technological determinism.

One may use the theory behind activity analysis to illustrate this point (Fig. 2). In a two-input (K–L) plane, assuming a linear production function with constant returns to scale, production techniques may be represented by activity rays from the origin; each ray corresponding to one particular type of technique used in the production of a certain product.

Three such techniques (T_1, T_2, and T_3) are assumed in Fig. 2. If points such as A, B, and C indicate the respective exclusive use of a particular technique at the unit level, then an isoquant ABC can be drawn. Such an isoquant turns out to be neither right-angled nor perfectly continuous. Within a certain range, say AB, the rate of substitution tends to remain constant and, thereafter, it takes a sudden jump. Thus, within ABC, a range of choices is possible that involve technologies T_1, T_2, and T_3 and their adjacent input-vector combinations (i.e., AB and BC). Presented this way, choice is still valid under partial fixity.

General literature survey

After a brief survey of the theoretical approaches to technological choice, I now turn to specific case studies for an empirical illumination. These studies are also relevant to the present study for several reasons. First, they generate useful insights into specific methodologies used in analyzing them. Second, they may reveal certain knowledge gaps that may necessitate further inquiry. Third, they indicate

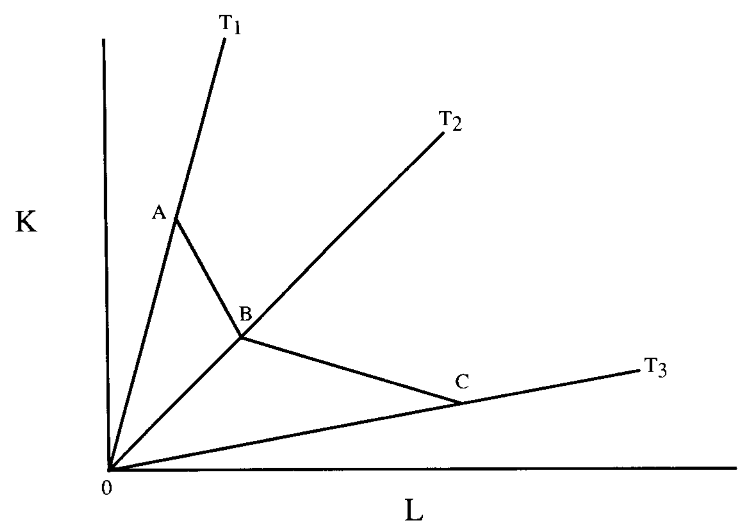

Fig. 2. Choice of technique under partial fixity.

areas where one can avoid duplication of efforts of other researchers and, finally, they are useful as a basis on which to compare my own results.

Most empirical studies on technology choice have revolved around testing the neoclassical versus technological rigidity hypotheses. That is, whether a feasible choice of technology exists or not and, where it exists, what factors influence such a choice. For analytical purposes, such studies may conveniently be grouped into three broad categories:

- Econometric studies on factor substitution,
- Engineering or process-analysis studies, and
- Anecdotal evidence studies.

Econometric studies

Most of the studies, particularly those before 1970, relied on statistical estimation of the elasticity of substitution to determine the possibilities for efficiently substituting labour for capital. Such estimates have been made for the whole manufacturing sector in single countries and for individual sectors within manufacturing for both cross sections and time series. Estimates also exist using cross-country data — among surveys purely devoted to econometric studies on factor substitution are those by Gaude (1975) and Morawetz (1976). (For an all-inclusive review, see Acharya (1974), White (1978), Pack (1982), and Moore (1983)).

Elasticities significantly above zero have been found in many industries suggesting considerable scope for factor substitution. However, such estimates should be interpreted with caution. The debilitating conceptual and measurement defects involved in these studies have been widely discussed by several authors — these include Arrow et al. (1961), Walters (1963), Nadiri (1970), O'Herlihy (1972), Morawetz (1976), and White (1978). In short (Morawetz 1976:11–12),

> They include aggregation and definition of capital, labour and outputs; the assumption that there are only two factors of production, ... difficulties in incorporating technical change, working capital and varying rates of capital utilization over time; the assumption that capital is putty–putty, whereas in reality it seems more like putty–clay; ... distinguishing between long-run and short-run elasticities; simultaneous equations bias; multicollinearity; and the varying reliability and appropriateness of available data.

As a result, the estimates obtained have been not only inconclusive but also inconsistent. Gaude (1975), for example, notes that estimates differ between cross-sectional and time-series data and may not even be easily comparable within a single set of data. Morawetz (1976) has also shown that there is little consistency among the cross-section studies in their rankings of common industries by estimated elasticity of substitution.

The importance of the elasticity of substitution as an indicator on which to formulate policy can nevertheless be underestimated, particularly for a country such as Tanzania that faces unemployment problems. A low elasticity of substitution might explain partly the existence of unemployment in such an economy because a low-wage policy fails to induce the adoption of labour-intensive methods of production (Eckaus 1955). If factor substitution is easy, however, the problem of unemployment can be combated without necessarily sacrificing output growth because the relatively faster-growing factor can be substituted easily for the slower-growing one. In addition, a high elasticity of substitution could also ease an economy's inflexibility in response to external shocks. For example, an exogenous oil-price shock can be partially absorbed by adopting oil-saving technologies.

These methodological problems do not necessarily invalidate the usefulness of econometric methods per se, but only the way in which they are used in specific case studies. The utility of these methods could, therefore, be greatly reinforced by more careful, detailed, and less aggregated direct field investigations that focus on a particular industry within a given socioeconomic environment.

Engineering and process-analysis studies

In engineering and process-analysis studies, researchers use both engineering information and data from operating plants to determine substitution possibilities within individual manufacturing processes or individual products. Three variants of these studies exist in the literature. One category of study uses a method that relies on the construction of a normal isoquant (see, for instance, studies by Timmer (1972), Cooper and Kaplinsky (1975), Pack (1975), Stewart (1975, 1977), Rhee and Westphal (1977), Kaplinsky (1984, 1987), and Stewart, D.F. (1985)), whereas a second variant delineates a synthetic isoquant. The third category of studies constructs an index of technical rigidity based on physical barriers.

Studies in the first category measure the actual inputs that operating plants require to produce a homogeneous product in a country or group of countries. Given the measured inputs (labour, capital, materials, etc.), a set of efficient technologies is established; each efficient technology in use will thus appear as a point on the usual isoquant. Efficient technologies can then be ranked according to their discounted present values.

In the second method, data are obtained from both engineering records and from individual factories in a large and varied set of countries. A set of alternative technologies is identified for each stage or subprocess in the production line. By assuming that the choice at one stage does not limit the range of choice in the preceding or succeeding stages, synthetic technologies are constructed by theoretically marrying various alternative parts of the production process — "synthetic" in the sense that a particular combination of processes postulated may never have been used in a real plant although the constituents have (see, for example, studies undertaken at the David Livingstone Institute, University of Strathclyde (1975)).

In the third variant, Forsyth et al. (1980) have established the limits of factor substitution by constructing an index of technical rigidity (ITR) on the basis of eight physical barriers to the substitution of labour for capital. Factors identified as being associated with barriers to labour use include: presence of fluids; high- or low-process temperatures; need for high-speed operations; use of electric power and high load factors; indivisible heavy material; and special hazards. The ITR takes values ranging from 0 (easy substitution) to 8 (little or no substitution). Of the 181 products covered, only 13 products have an ITR as high as 6 or 7 suggesting that substantial substitution possibilities exist in many production processes.

The overall evidence from engineering or process-analysis studies has demonstrated possibilities of factor substitutability and, within the examined processes, differences in factor ratios can be quite substantial. Timmer's (1972) study on rice milling in Indonesia, for instance, found that investment requirements per worker in the most capital-intensive plant was 93 times greater than those in the most labour-intensive one. Uhlig and Bhat (1979) examined choice of technique in maize milling at a subprocess level. They found limited choice of technique in the core milling section of a modern roller mill but documented substantial cost variation in capital and labour in the peripheral packing activity. Wide variations in factor ratios have also been reported by Stewart (1977) in her maize-milling study in Kenya.

Pickett (1977) summarized the evidence established by the extensive studies of the Strathclyde group by observing that they have succeeded in demolishing the prevalent notion of technological determinism. This sentiment was also echoed by Baron (1980) when summarizing studies on food processing. However, some open questions in the engineering and process analysis studies still remain. Substitution possibilities are still, in some cases, being analyzed within the traditional labour–capital input mix. Also, where other factor inputs have been considered, questions of interpretation regarding the definition and values of capital still persist. Moreover, the number of products and industries covered has been distinctly limited, particularly in heavy industries (Moore 1983). This approach, however, has the merit of less reliance on the strong assumptions embodied in the pure econometric studies. As Pack (1982:3) notes, the microanalytical orientation of these studies

> also has the appeal of the concrete: not only can the curvature of a given isoquant be determined; the specific set of interrelated machines and processes corresponding to a given capital–labour ratio can also be identified.

Anecdotal evidence studies

Studies of anecdotal evidence use data collected from actual plant visits in developing countries to determine substitution possibilities without necessarily establishing the numerical range of substitution (as the econometric studies) or the frontier of efficient combinations (as with the engineering and process studies. Pack (1976), for example, documented examples of capital–labour substitution in consumer-goods manufacturing in Kenya. He showed that substitution options are found in peripheral activities but noted quality problems such as high rates of spoilage and breakage due to human handling of fruits before processing. Substitution options are also reported by Ranis (1973). He reported that, in core processes, labour-stretching options include extra use of equipment through extra shifts and greater use of older equipment.

Anecdotal evidence on possibilities of factor substitution has also been inferred from observed factor-intensity differentials between small and large firms. It is widely reported that small firms employ production techniques that are efficient, profitable, and generate more jobs with lower capital outlays than techniques employed by large firms. Thus, given the large number of small firms, more jobs can be created even at a slower growth rate (Liedholm and Parker 1989:6).

In a recent survey, Bagachwa and Stewart (1989) cited evidence that shows that the cost of capital per job in large-scale firms ranges from 4 to 20 times that of smaller firms in the case of Kenya, 20 times in Ghana, and 18 times in Sierra

Leone. Small-scale production techniques have also been reported to possess lower costs per unit of output than large-scale techniques indicating a farmer's relative static efficiency. This is so particularly in modern product lines such as baking, tailoring, carpentry, metal working, and repair (Cortes et al. 1987; Liedholm and Mead 1987). Such a response by small firms has been interpreted as being consistent with domestic resource availability and therefore suggestive of efficient factor-substitution possibilities.

Comparisons between small and large firms are fraught with difficulties, however. Ideally, such comparisons should be made where the final product is homogeneous with both firms being vertically integrated to the same extent. Unfortunately, less attention has been paid to the problem of vertical integration — probably because correction measures entail a very difficult task of estimating shadow prices. Another problem is that if small and large firms produce different products, then they are bound to face different production functions, in which case different technologies cannot be represented by a single isoquant and a comparison of factor-intensity differentials between large and small firms becomes meaningless.

By and large, anecdotal evidence has further shown that feasible technological choices exist in developing countries. The use of greater labour intensity is primarily attributed to lower volumes and lower wages, good flexible management, and existence of both internal and external competition in product markets. These studies, however, by failing to delineate a fully articulated isoquant, do not tell us much about the optimal mix or the numerical range of the identified substitution possibilities.

Policy concerns and further evidence from Tanzania

Policy concerns

Implicit policy concerns about appropriateness of technology for Tanzanian conditions began to emerge after the Arusha Declaration (1967). However, it was not until the Third 5-Year Plan period (1976–81), that a more serious attempt was made to address to this question. Hitherto, both the 3-Year Plan (1961–64) and the subsequent comprehensive First 5-Year Plan (1964–69) had paid little attention to such structural aspects as ownership relations, enterprise organization, linkage effects, product mix, and technological choice (Rweyemamu 1973).

During the pre-Arusha Declaration period, overall development policy was also conceived in conventional terms. The policy sought to achieve two major objectives: rapid growth in per-capita income and national self sufficiency in high- and middle-level personnel. This was to be achieved within a mixed, but predominantly market, economy framework that relied heavily on private (mainly foreign) efforts, particularly in the directly productive sectors. For example, during the First 5-Year Plan, it was envisaged that 75% of the investment in industry would be undertaken by private sector agents (see URT 1964:98, table 2.6).

The benefits of international capital inflows were then expected to trickle down into the emerging indigenous business community through technological transfer, i.e., through capital availability, provision of foreign skills to train nationals, management and engineering design, and marketing facilities. The success of the then-current industrial strategy of import substitution was to be judged in terms of high rates of growth and its capability to raise industry's share in the gross domestic product (GDP).

These policies, however, fostered a number of unfavourable trends. Technological, market, and financial dependencies on the volatile world market began to increase. Internally, a privileged class of urban elite began to emerge as a result of an inappropriate education system and the "Tanzanianization" process. Urban–rural income differentials also began to widen because of relative neglect of a broad-based strategy of rural development. These unfavourable trends prompted the Tanzanian leadership to seek remedial measures that became enshrined in the Arusha Declaration (1967).

With the Arusha Declaration, policy for future development was to revolve around four overlapping themes: socialism, rural development, self-reliance, and economic growth. Socialism was seen as the only effective political mechanism that could ensure effective control over the major means of production, more equitable and egalitarian income distribution, and a guaranteed increase in participation by workers in the decision-making process.

The need for pursuing a broad-based strategy for rural development is obvious. It stems from the realization that, because more than three-quarters of the Tanzanian population live in rural areas, any meaningful policy for development must somehow be addressed to the means and conditions of the rural majority. The objective of self-reliance is to ensure increased indigenous control over the disposition of both human and economic resources. This stems from the desire to reduce dependency on external finance, personnel, technology, and markets for primary exports. Finally, economic growth is seen as a necessary prerequisite for attaining all other objectives.

Thus, the Arusha Declaration represents a basic statement on Tanzania's long-term objectives. As far as industrial development and technology policy are concerned, however, the Declaration highlights only one important aspect that relates to enterprise organization. In particular, the Declaration explicitly specifies those areas of industry that should fall under government control, joint ventures, and private ownership. Apart from this, the Declaration is silent over:

- What means industry should use to achieve the stated objectives,
- What type of products (i.e., product mix) industry should produce,
- What criteria should be used in choosing technology within an industry, and
- To which markets should products be sold.

To remedy these deficiencies, the Long Term (1975–95) basic industry strategy (BIS) was formulated. The BIS contains a clearly delineated set of objectives to guide future investment opportunities in industry. Its overriding twin objectives are structural transformation and self-reliance. These embrace six distinct subgoals:

- Industrial growth,
- Structural change toward greater interindustry linkages through increased capability in producer goods,

- Strengthening national autonomy through reduced reliance on world trade, technical assistance, and foreign-investment aid,
- Employment creation,
- More equal distribution of individual incomes and development gains among regions, and
- Greater participation of workers in the management of their firms.

The BIS sets out clearly criteria for activity choice. First, an industrial activity is to be chosen primarily on the basis of its ability to enhance self-reliance and structural change. Efficiency considerations, comparative advantage, and ability to compete in international markets are to be accorded secondary importance. Second, top priority should be given to a core of strategic or basic industries. These should be those that either enter directly and indirectly into production of a wider range of industrial inputs (high-linkage goods) or industries supplying minimum mass needs of food, shelter, health, education, and transport (wage goods). Third, to enhance self-reliance, particular emphasis is placed on the use of domestic resources.

Production is also to cater primarily for local markets. To enhance self-reliance at the village level, the BIS recognizes the need to design and implement a small-scale industry program. It was not clear, however, what precise role the small-scale industries were to play in the industrialization process and, as Skarstein and Wangwe (1986) observe, the link between small- and large-scale industries thus remained unclear and vague. Lastly, the BIS envisages that product choice for basic mass needs would be defined more by central planners and less by effective demand.

However, the BIS is not explicit on the question of technology choice within a given industry. Ambiguity and, indeed, conflict of objectives are, therefore, likely to arise particularly when inference is based on such general objectives as structural change, employment generation, regional dispersal of industries, and industrial growth. For instance, if industrial growth is to be fostered, the long-run implication is that surplus generation and reinvestment rates will have to be high. This can only be sustained if cost of production is kept low. On the other hand, if employment expansion is to be pursued, relatively labour-intensive technology will be preferable.

Greater labour intensity is also more likely to be consistent with the program of extending industry in the countryside through small-scale operations. Also, given the need to enhance self-reliance and the lack of indigenous technological capacity, there is an implicit suggestion for using technology that places less demand on skilled labour and that has the potential for local adaptability. However, as I show in Chapter Five, the pursuit of an objective of maximizing surplus may imply a different technology from that implied by an objective of maximizing employment. It is not clear then, whether all industrial activities will have to use labour- or capital-intensive processes or whether each category of production techniques will be confined to certain activities. In other words, "it seems that explicit thought was not given to the role that choice of technology could perform to facilitate the realization of the principles of and implementation of the BIS" (Skarstein and Wangwe 1986:57).

It should also be emphasized that background studies to the BIS clearly show that the primary choice of the BIS was on its potential for achieving the objectives of structural change and self reliance. Otherwise, the BIS ranked industrial growth and employment generation objectives second and last. When formulating the long-term industrial strategy, the BIS was considered along with four other alternative development strategies. These were

- The maximum-growth strategy that sought to minimize the investment–value added ratio,
- The small-scale industry strategy,
- The eastern African strategy that envisaged specialization in certain products in which Tanzania had a comparative advantage in relation to other eastern African countries, and
- The mixed strategy.

The maximum-growth strategy ranked first in terms of fostering industrial growth; and the small-scale industry strategy ranked first in terms of employment generation and promotion of regional equality (for details, see Roemer et al. (1976) and Skarstein and Wangwe (1986)).

It is quite logical to expect that policies on choice of technology under the BIS should emphasize the enhancement of structural change and self-reliance. One should also expect that actual investment choices should reflect such features. It is not my intention to assess the merits and demerits of the BIS, particularly in relation to the question of choice of technology at the national level. However, the general picture is that, even after the formulation of the BIS, Tanzania still lacked an explicit technology policy.

Evidence from past studies

In spite of continued government emphasis and interest on questions of choice of technology, relatively little is known about the potential implications of existing technologies within context of the prevailing Tanzanian environment. The literature on the subject, even that pertaining to industrial technology in general, is very scanty. Certainly, no detailed studies on the economic implications of alternative technologies in the grain-milling industry have been carried out.

Among the few studies available, Rweyemamu's (1973) work carries an important policy message for choice of technology questions generally. His findings revealed the nature of the entrepreneur (ownership pattern) to be a critical parameter in moulding decisions of technological choice among manufacturing firms in Tanzania. Using single-equation regression techniques, he demonstrated that foreign-owned firms use technologies that are relatively more capital intensive than locally owned firms. The observed factor intensity differentials were attributed to differences in investment motives, factor prices, and accessibility to technological information among entrepreneurs. It is possible, however, that the heterogeneity of output in this sample could mask a certain product-specific impact on the technologies analyzed.

Roemer et al. (1976) have also attempted to analyze the macroeconomic implications of factor substitution in Tanzanian industry. They investigated the implication for aggregate employment of adopting both labour- and capital-intensive strategies in Tanzania for a 20-year planning horizon (1975–95). They found that if the government were to maximize employment and value added then the labour-intensive strategy should be preferred. With a given output mix and the same level of investment, job creation would be 35% higher and value added 5% higher than the most capital-intensive strategy would allow. Their study demonstrated the possibility for simultaneously increasing employment and output in Tanzanian industry. This result, however, depends crucially on the limited assumption of a two-alternative technology strategy. It would have been more instructive, however, to make an additional assumption that would have allowed for an optimal mix strategy where both labour- and capital-intensive technologies can be employed simultaneously in the different branches of industry.

In another study, Joseph and Nsengiyumva (1981) used an indirect method of estimating the constant of elasticity of substitution (CES) production function to establish estimates of elasticity of substitution for five productive sectors and three Tanzanian manufacturing industries. Estimated sectoral elasticities of substitution revealed only limited substitution possibilities ranging from 0.56 for manufacturing to 0.07 for agriculture. In the three branches of manufacturing studied, estimated substitution elasticities were highest in textiles (2.08) followed by chemicals (0.72) and lowest in food manufacturing (0.23). Although indicative of feasible possibilities of technological choice, these results must be interpreted with caution as the previous analyses on pure econometric studies have shown.

In his study, Williams (1976) used a methodology akin to process analysis to investigate the determinants of technology choice in five major textile mills in Tanzania. He established that capital intensity varied from 0.45 to 0.21 across the five mills, a range that "would have permitted considerable substitution of labour for capital." He also noted that, although the most labour-intensive mill was also the least-cost one, when making a decision to expand the industry in 1974, the two most capital-intensive mills were selected.

Williams then concludes (1976:58) that even "on the narrow grounds of simple appropriateness on national objectives, the technology chosen was not the optimal choice." Neither could such a choice be explained from simple profit-maximizing behaviour nor from the "engineering man" objective. The real determinants lie in the realm of politics and the nature of the political decision-maker (bureaucrat) who acts as if the only choices available were the capital-intensive ones, thus ignoring or being unaware of the labour-intensive options.

Mlawa's (1983) study on textiles in Tanzania attributes the inconsistency between actual technological choices and national objectives to the absence of a national technology policy generally and the lack of indigenous technomanagerial capabilities at the firm level. Otherwise, he points out "it would be idle to presume that foreign engineers, machinery suppliers, consultants, and financial donors would necessarily ensure that Tanzania's policy objectives were (and would be) brought to bear on the investment process" (Mlawa 1983:153).

In a few studies that have dealt with some aspects of choice of technology in grain-milling industry in Tanzania, the employment impact of technology has been emphasized. Phillips (1976), for example, noted that regardless of the associated costs of infrastructural investment large grain mills were considerably more capital-intensive than small ones. He then concluded that considerable employment benefits could be associated with more decentralized small-scale milling plants. His study was confined to maize milling and he did not consider product characteristics, locational factors, service characteristics, and other inputs apart from machinery and labour.

Perkins' (1983) study of 10 major industries, including maize milling, showed that large-scale maize-milling units using advanced roller-mill technology had average capital–labour ratios of 2.4 times higher than small-scale milling units. The latter were also more efficient in the use of capital than large-scale mills.

A more general study on grain-milling industry in eastern Africa was undertaken by ILO/JASPA (1981). This was a comparative subregional study covering four eastern African countries: Kenya, Somalia, Tanzania, and Zambia. Among its findings was the observation that neither the small-scale hammer mill, nor the large-scale roller mill were unequivocally superior on cost grounds. However, given the need for employment creation and the need to economize on the use foreign exchange, the balance was tilted in favour of the hammer-mill technology. On consumption attributes, the study revealed that most consumers preferred the finer and well-sifted flour of the large-scale roller mill to the whole meal of the custom mill. The study was limited to maize milling, however, and its utility is limited by the use of cross-country data that could mask country-specific technological differences.

Building on this base of scanty but useful information, this study seeks to extend the analysis on technology choice in the grain-milling industry in Tanzania on basically two fronts. One is to widen the population by including rice milling as well as maize milling. It is hoped that this will make the results more representative to the grain-milling industry as a whole than the previous ones. I would have liked to include wheat milling but unfortunately the observations are not sufficient to warrant a meaningful analysis. Second, most studies on technology choice in Tanzania have not systematically analyzed factors that influence technological choice between different size categories of firms. This study, apart from being concerned with static aspects of efficiency (i.e., employment generation and cost minimization), attempts to explore the determinants of technology choice in the Tanzanian grain-milling industry. The analysis also attempts to generate additional insights as to whether small and large milling establishments use different technologies and whether they face different technological constraints.

Emerging issues

Despite diversity in the underlying assumptions, content, and coverage, both the theoretical approaches and available empirical studies generate useful insights that contribute to a more adequate understanding of the nature of technological choice. Two particular insights that are worth noting relate to the definitional problem and the complexity of technology choice.

Conceptually, the analyses have demonstrated the need to view technology in a wider context. In particular, the tendency to identify technology simply as the hardware of production, i.e., knowledge about machines and processes need to be challenged. It is necessary, therefore, to conceive technology in a broader context encompassing both the hardware and software components. As already indicated, the software component comprises the skills, knowledge, and procedures necessary for designing, producing, or acquiring a given product or service. Any piece of hardware equipment is just a portion of the technology package. The two technology components should, therefore, be regarded as complementary.

Defined this way, technology cannot operate in a vacuum. Rather its character and evolution will be shaped by a set of socioeconomic processes (i.e., the way production is organized, pattern of income distribution, and availability and allocation of resources). It is this productive structure that provides the seedbed for the evolution of technology and determines its use. As a feedback, technological development removes constraints and provides the productive system with new opportunities to expand.

This view allows one to go beyond the neoclassical contention that technology choice is simply a choice between capital- and labour-intensive processes. Rather, we conceive it as a complex process involving both technical and institutional variables. To visualize more schematically the complexity of this choice, let us consider for expositional purposes the grain-production process in Tanzania.

Five stages may be identified in the processing of grain: planting, weeding, harvesting, milling, and cooking. At each stage, the production process is carried out in a separate activity. Each activity uses inputs from other activities and generates output for the subsequent activities in the chain. The five activities appear as a chain; and each activity may be using technology that is quite different (in terms of input requirements, size, quality, etc.) from the others. By implication, the type and range of choices of technology is likely to vary across activities.

One of the complications that arise when making decisions on choosing between alternative technologies is that posed by Stewart (1977): that is, whether it is meaningful to speak of technology choice as applicable for the whole chain or only for a particular activity in the chain. It is possible that an examination of the whole chain might alter the conclusion from looking at one link. Because of problems of aggregation, one might be tempted to analyze technology choice at the activity level. To be meaningful, however, such an analysis must capture the impact of externalities arising from the interdependence of production. A long-standing criticism of process-analysis studies is that they consider technologies at the final stage of production, thus ignoring intermediate stages and their associated production processes (Bhalla 1975).

Perhaps one way of getting around the problem is to establish the degree of interdependence among activities. If it is slight, then one may assume the bias arising from analyzing choice decisions at the activity level as being negligible. On the other hand, if the degree of interdependence is high, the decision-making process might have to be analyzed for the whole chain. Definitely, the degree of interdependence is a relative notion. In the case of grain-milling, it is assumed in this study that the degree of interdependence between activities is very slight. The concept of interdependence is used here in a very narrow sense. In particular, it is used to refer to the extent to which the choice of technology at one stage (activity) influences or limits the range of choice in the preceding or succeeding stages. More specifically, it is assumed that the choice of technology in the milling activity is not influenced or limited by choices in the preceding activities (planting, weeding, and harvesting) or in the succeeding activity of cooking.

Second, even if analysis is carried out at the activity level, a closer examination

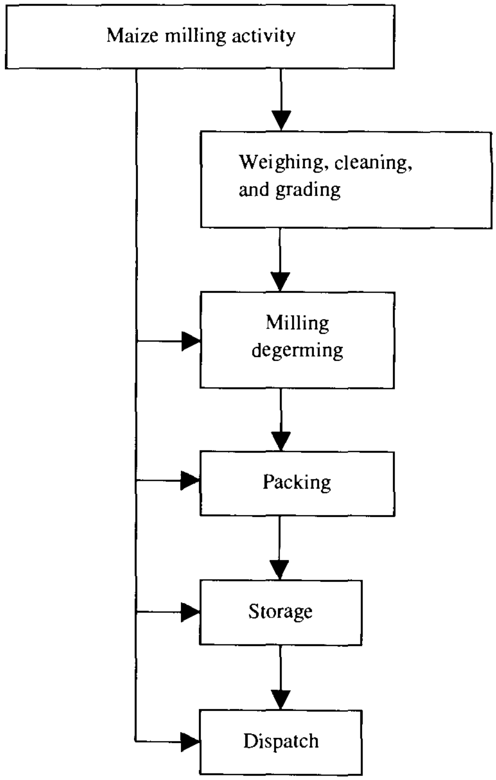

Fig. 3. The maize-milling process.

of each activity might reveal a number of vertically integrated subprocesses that may further complicate the choice of technology. In the maize-milling activity, for example, apart from the core process of milling, a number of peripheral subprocesses exist. They range from preparatory subprocesses of weighing, cleaning, and grading to the finishing subprocesses of packing, storage, and despatch (Fig. 3).

From the viewpoint of production theory and the perspective of technology policy, the character of core and peripheral substitution are of interest. This is particularly so because, in certain branches of developing country industry, it has been found that potential labour-using opportunities are mostly to be found in peripheral rather than core operations (see some studies by Ranis (1973), Pack (1976), and Uhlig and Bhat (1979)). This is also of interest from the analytical point of view because the extent of vertical integration may influence the factor intensity of a given technology, thereby introducing a bias in the selection mechanism. Thus, for example, if a large merchant mill packs its products but a small custom mill does not, apparent differences in factor intensity may reflect this difference in peripheral subprocess rather than substitution in the core production process.

Third, technology as a package exhibits horizontal linkages. Horizontal linkages develop with the introduction of new equipment. For example, the introduction of a grain-milling machine may impose, besides direct input requirements (labour and raw material), a new set of complementary investments. Bulk storage may necessitate the building of a silo. A laboratory may be deemed necessary if quality control is to be ensured. Further, infrastructural investments may be required to bring power and water within the factory site. Such complementary investment links reinforce the conception of technology as a package and discourages the idea of assessing a piece of equipment individually.

Lastly, institutional characteristics such as the type of entrepreneurs (and the way they are organized) may also influence technology choice. The grain-milling industry in Tanzania is, for example, organized along three lines: household, custom, and merchant milling.

- Household milling is primarily a noncommercialized activity catering to subsistence consumption needs.
- Custom mills, whether privately or cooperatively owned, are commercialized units serving customers, who supply their raw grains, for a fee. Thus, they serve the vicinity market and depend on customers having easy access to the mills.
- Merchant mills are large commercialized units that purchase grains from peasants or the state marketing institution and process them into finished products that are sold in packaged form. In Tanzania, merchant milling is monopolized by the National Milling Corporation (NMC), a state-run parastatal.

As I show later, the institutional set up has an important bearing on the type of technology to be used, location of the plant, and type of product to be produced.

One important aspect that emerges out of this introductory analysis is the scale factor. As noted above, small-scale custom mills coexist with large-scale merchant mills. Analytically, this suggests the need to introduce an explicit assumption that must take care of the bimodalism of such an industrial structure. This is crucial for two reasons. First, the grain-milling industry is not an isolated incident because, generally, small-scale firms in Tanzania are quantitatively important employers in manufacturing industry accounting for more than 20% of the total manufacturing employment (Havnevik et al. 1985). Second, the scale factor is crucial because of the wide belief that significant differences in terms of market orientation, product quality, and accessibility to technological information exist between small and large firms. They are thus likely to face different technological constraints.

Suggested hypotheses

Three major empirical research questions emerge out of the previous discussion. They relate to factor intensity, existence of technology choice, and determinants of technology choice. The first major empirical issue to be investigated centres on the relative factor intensity between small and large firms. In particular, three propositions can be postulated.

First, *technology choice is not invariant to scale*. Small-scale milling firms tend to be relatively more labour intensive than large-scale mills. This proposition is based on the widely accepted view that small firms have a lower wage–rental ratio

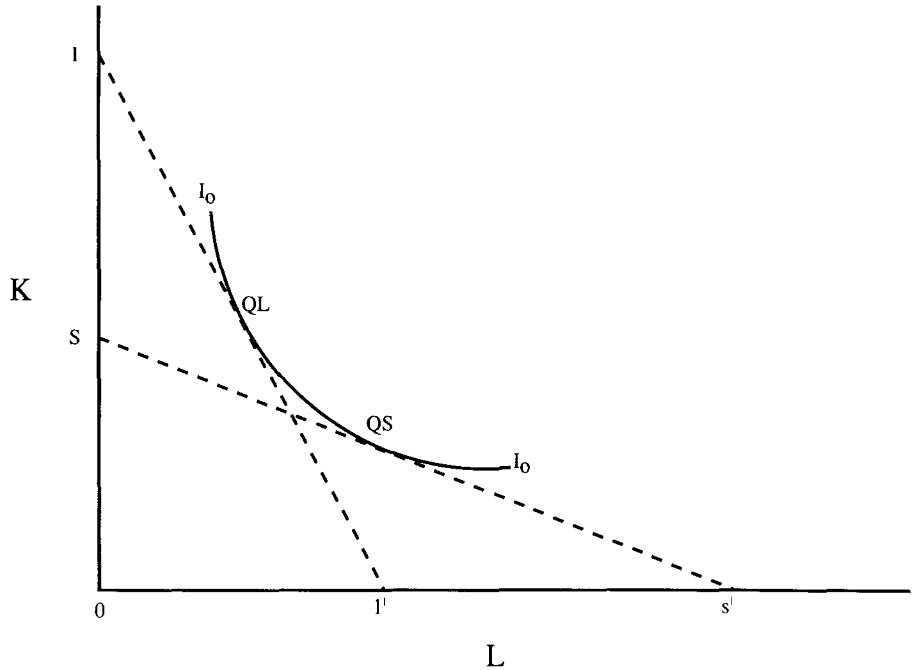

Fig. 4. Case of single production function.

because they pay more for capital funds (capital markets in most developing countries are highly segmented; the high unit cost of administering small loans coupled with high risk of default among small operators induce credit institutions to discriminate against small-scale borrowers) and tend to employ relatively more unskilled labour than large firms (Fig. 4).

It is assumed, for expositional purposes, that all firms in the industry employ two primary inputs — capital (K) and labour (L) — in a well-behaved linear homogeneous production function. An isoquant such as IoIo is a locus of points representing minimum input combinations required to produce one unit of output with existing technology. If, for reasons given above, capital is cheaper for large firms, as given by isocost ll′ (Fig. 4), these firms will opt for a capital-intensive technology as represented by point QL. If a small firm, on the other hand, faces a relatively low wage–rental ratio (isocost ss′), it will adopt labour-intensive technology at the optimum, QS.

Because plants QL and QS lie on the same isoquant, Io, and if the two isocost curves are assumed to show the same amount of unit costs, technologies employed by the two plants are efficient technically and in terms of price. Movement from QL to QS will represent efficient substitution along the production frontier. If it is further assumed that the Io is a CES production function, its estimation will reveal same elasticities of substitution between capital and labour for both small and large firms.

This situation only obtains when all firms have the same access to, and employ the same technology, i.e., when both small and large firms face a single production function. This need not be the case, however, and possibilities of multiple production functions across different size groups cannot be ruled out.

This prompts us to postulate the second, related, hypothesis: *small and large milling firms have different access to technology and thus employ different technologies*. That is, they face different production functions. If small and large firms do not have access to the same technology, they cannot be represented as points on a single frontier. Rather, they would appear as points on two different production functions.

There are several reason why small and large firms may differ in their decisions to choose technology. First, as Page and Steel (1984:135) point out, varying administrative and organizational structures among firms may lead to alternative decision-making rules. Second, small and large firms may not have the same access to technological information and may, therefore, differ in their levels of knowledge about the operating characteristics of technologies. Third, economies of scale may present more serious problems in smaller firms than in large firms. Lastly, the output produced by both small and large firms, although substitutable, may not be homogeneous (Page 1979:16). If the latter is the case, then comparisons between small and large firms on the basis of input–output ratios become less meaningful.

So far, I have assumed that there is a "shelf" of alternative technologies from which different entrepreneurs can make alternative choices. In other words, I have assumed that factor substitution is free. As this may not be the case, this assumption requires substantiation.

This leads to the third hypothesis relating to the existence and determinants of choice of technology: *within the grain-milling industry in Tanzania, there are possibilities for investors to make alternative choice in milling technology*. This proposition stems from observation that grain-milling equipment is not a homogeneous product. There are marked technical variations in terms of quality, sophistication, performance, and durability among milling equipment particularly when supplied by different manufacturers. Such product differentiation is a consequence of the disguised form of competition that the oligopolistic structure of the western European capital-goods industry serving overseas grain millers has assumed. Moreover, as far as there are significant differences in cost structures of the main suppliers of grain-equipment for Tanzania (i.e., Switzerland, the United Kingdom, and Germany), there is bound to be a wide range of equipment prices. Furthermore, the entry of local (Tanzanian) manufacturing firms into the capital-goods market may potentially widen the scope of technological choice for the local investor. Thus, even if technological progress in the developed countries might be assuming a labour-saving bias, given such a price–quality range, one should expect at least, ex-ante, some degree of variability in inputs required by different grain-milling technologies.

The rest of this study is devoted to the testing of these three hypotheses. Operationally, a qualitative analysis of the structure of the grain-milling industry in Tanzania reveals the direction to which institutional factors, such as product characteristics, policymaker influences, and market forces, bias decisions of technology choice. Factor intensities and possibilities for factor substitution are analyzed both qualitatively and quantitatively. The latter is achieved through a model designed within the neoclassical context of production-function analysis. To reinforce the utility of these analyses, a more disaggregated analysis is carried out using project-appraisal methods. This microanalytic frame permits us to assess the private and social returns to the proprietor and, hence, the economic viability of a given technology. However, before embarking on the detailed analysis, data sources, sampling frame, field surveys, and measurement problems are briefly discussed in Chapter Three.

Chapter Three: Study Area and Research Methodology

Choice of area of study

This study focuses on choice of technology within the grain-milling industry in Tanzania. Interest in this particular area stems from its relevance both analytically and in terms of policy. The late 1970s witnessed a shift in focus in studies designed to analyze technology transfer and choice issues. Hitherto, analyses had focused on the ex-ante investment problem of choosing technology. More specifically, the main preoccupation of these studies was the cost effectiveness and suitability of the technology transferred in relation to the resources available in the recipient country (Fransman 1984).

The recent approach, on the other hand, proceeds as if the ex-ante problem of "choice" had been solved. The major emphasis of the latter approach is on the explicit incorporation, within the analysis, of the dynamic variables that shape technological progress. Within this context, attention is focused on how and what happens to investment ex-post — that is, once technology has been chosen. The analysis thus boils down to how the input coefficients evolve over time as the acquired technology is mastered, adapted, or assimilated.

Our belief, however, is that although such a shift was useful and indeed raised a number of important limitations to the previous analysis (for example, earlier studies tended to underestimate the magnitude and role of local technological capabilities in the technological transfer process (Fransman 1984)), the question of technological choice still deserves serious attention, particularly in the developing countries. This is because, in the first case, the shift in focus cannot be interpreted as implying a "sudden jump" in the process of acquiring technology. Rather, it should be interpreted as implying a gradual and continuous change within this process. In other words, it is the technology in use that provides a seedbed from which technological progress stems. Consequently, the initial choice of technology has major consequences not only for plant layout, type, and nature of machinery and equipment to be employed but also on the overall production organization that shapes technological progress.

To elaborate on this point, the choice of technology may, for example, affect the size and nature of the market power that, in turn, influences the extent of research and development (R&D) activities. This point is clearly brought out by Katz (1973) who finds evidence consistent with the Schumpeterian hypothesis that large absolute size and market power are necessary to encourage R&D. He thus documents in despairing terms the weak research potential of small firms in Argentina's electrical goods industry. It is imperative then that a clear understanding of the forces that shape technological progress presupposes a clear grasp of the factors that mould technological decisions at the investment stage.

The second reason that prompts us to put the problem of technological choice within the conventional analytical framework, which emphasizes the relative cost levels and the potential economic suitability and effectiveness of alternative technologies, is certain unanswered questions relating to the range and determinants of technology. As pointed out in Chapter Two, despite the massive evidence generated by macroeconomic investigations on choice of technology, no simple generalizations can be made regarding the range and determinants of technologies in use. It depends on the nature of the industry, the nature and characteristics of products being produced, market organization, the entrepreneurial talents, and other environmental- and institutional-specific factors. In fact, in the case of Tanzania, it is not just a problem of the inconclusiveness of the evidence available but also the scanty and unreliable nature of such evidence.

Apart from this problem of limited information, the scanty empirical evidence on this topic implies that technological policy gaps also exist that suggest the need for more detailed and systematic studies. For example, it seems that, although the choice of appropriate technology has been expressed at the highest policy levels in Tanzania, little effort has been expended on articulating explicit technology policy in general and its relevance to the grain-milling industry in particular. Undoubtedly, the critical role of technology in issues related to employment generation and resource use has been recognized by policymakers, but only implicitly. Certainly, the absence of detailed studies appraising milling technologies has meant that policymakers can only rely on speculation when making specific policy recommendations.

Furthermore, a problem of technology choice exists because, despite high levels of underused industrial capacity, capacity expansion continued unabated in Tanzanian industry in the 1970s and 1980s (Wangwe and Bagachwa 1988). A problem of technology choice also exist because most of the technologies currently in use in Tanzania were developed in advanced countries with different social, economic, and cultural conditions from those in Tanzania. Such advanced-country technologies may be unsuited for Tanzanian conditions.

Interest in the grain-milling industry stems from its relevance to policy in a development strategy oriented toward basic needs that is currently being pursued in Tanzania. Cereal grains constitute an important component of the primary wage good — food — not only in Tanzania but also in most developing countries. The 1976–77 Household Budget Survey (HBS) conducted in Tanzania showed that, for low- to medium-level income groups, consumption expenditure on the major grains (maize, rice, wheat, and sorghum and millet) accounted on average for about 35% of a household's total expenditure. Furthermore, estimates by the Tanzania Food and Nutrition Council (TFNC) show that the average annual domestic per-capita consumption of food grains is about 130 kg, an equivalent of 30% of the total food consumed. Consequently, and as seen from the HBS data (Table 1), cereal grains are a major source of calories, accounting for over 75% of the total staple calorie intake in Tanzania.

It is, therefore, not surprising that the food-processing industry constitutes a vital element in the vector of "basic" industries in Tanzania. The industry contributes about 20% of the total manufacturing value added and employs about 22% of total

Table 1. Staple food calorie intake in Tanzania.

	Calories[a] from staple foods (%)		
	Rural	Urban	Total
Maize	62	53	61
Rice/paddy	8	24	12
Wheat	0	2	1
Sorghum and millet	8	5	7
Cassava	13	11	12
Potatoes	5	3	5
Bananas	4	2	2
Total	100	100	100

Source: Marketing Development Bureau (MDB): Price Policy Recommendations (1984–85); based on Household Budget Survey (1976–77).

[a] Foods have been converted to calories using a composition table from the Food and Agriculture Organization.

manufacturing employment annually (TISCO 1980). Furthermore, the grain-milling industry obtains raw grains from the rural areas and distributes its milled products to the increasingly overcrowded urban centres. It is apparent then that the economic implications of technology choice will not only affect this industry directly but also a significant proportion of the rural and urban population indirectly (through production and income linkages).

Another reason for undertaking this study stems from the renewed interest in promoting small-scale industries by policymakers in Tanzania. Small-scale industrial development is currently regarded by the policymakers as being consistent with Tanzania's distinctive *Ujamaa* policy of rural development and self reliance. It is thus widely believed that small-scale firms are relatively more labour intensive, can use more domestic resources, and could be more geographically dispersed than large firms. If this is so, then adopting and developing small-scale custom-mill technology will be appropriate to domestic resource availability and should be expected to generate substantial employment opportunities in the grain-milling industry, at least in the short run. If, on the other hand, such labour-intensive small firms do not use capital effectively then, irrespective of the time frame, a conflict will arise between a policy objective that seeks to maximize employment and one that seeks to maximize output.

Apart from these policy considerations, the scale factor is analytically considered crucial because of the wide belief that significant differences in terms of market orientation, product quality, efficiency, work organization, resource and factor use, and geographical distribution exist between small- and large-scale enterprises. Small and large enterprises are, therefore, bound to confront different production functions and to face different technological constraints. Unfortunately, the existing body of empirical research has not considered technology choice options in small-scale manufacturing nor has it measured the efficiency of production in smaller firms, relative to large firms.

Additionally, estimates by the World Bank (1980) reveal that the present operating milling capacity lags behind demand for grain-mill products. In fact, the government is currently considering whether additional investment should be directed to rehabilitating the existing National Milling Corporation's (NMC) large mills or purchasing new large mills, or encouraging private investment in small mills. It is strongly felt that this study would provide extra insights regarding the appropriate form of investment to be undertaken in this subsector.

Lastly, the specific focus of this study has also been made on grounds of operational strategy and convenience. Grain-milling is part of the processing industry and it is widely argued that the limitations on choice of technology are most severe in manufacturing (Cooper et al. 1975). Thus, grain processing seems to offer some clues as to what these constraints are in the Tanzanian context and how binding they are. The grain-milling industry in Tanzania offers a good example of an industry with a reasonable range of technologies. Existing milling technologies range from traditional hand grinding through small-scale custom hammer-mill technology to large-scale merchant roller mills. Grain-milling plants are found not only in urban areas but also in rural market centres. The industry, therefore, is likely to show marked differences in terms of the scale of operation, factor intensity, and resource economy: aspects that are the focus of the proposed empirical inquiry.

It is for these reasons that the problem of choice of technology in the grain-milling industry has been identified as an important economic area to be studied. The scope of this study is limited to maize and rice milling, however. Maize is the most important food crop, grown by more than 50% of Tanzanian peasants for both subsistence and commercial uses. Maize is also the dominant source of calorie intake in Tanzania and accounts for 61% of the total (Table 1): although the percentage is a bit lower in urban areas, it is still above 50%.

Rice is also an important subsistence crop in Tanzania and second only to maize in terms of volume and value of crop marketed officially. Rice contributes about 12% of the total (nationwide) calorie intake. It is, however, much more important in urban areas where it provides almost 25% of total calories. Wheat is consumed mainly in urban areas and contributes the least calorie intake — only about 1% nationwide. Thus, apart from being preferred staples (to sorghum and millet), maize and rice are consumed country wide and cater to various levels of income groups and consumption tastes. Moreover, unlike wheat milling, maize- and rice-milling firms are quantitatively well represented and offer a reasonable size range of technologies in use. The latter aspect was useful in permitting a meaningful sample to be drawn up for the present study.

Pilot survey

To obtain the necessary data, a two-phase survey was undertaken. In phase one, it was necessary to do a preliminary (pilot) survey to find out the economic basis for stratifying the sample because no adequate alternative sampling frame existed. Although official statistics list milling firms by size of employment, none contains the type of technology employed. The pilot survey covered both Dar es Salaam and Arusha. The main objective of the pilot survey was to enumerate and list as many milling firms as possible so as to get a comprehensive picture of the different technologies employed. The survey involved administering a brief questionnaire covering such general information as address, location, nature of activity, employment, and type of equipment employed. A total of 170 firms were covered in the pilot survey.

This baseline information formed the basis for stratifying the milling activities and the subsequent sampling frame. Before sampling could be done, stratification was necessary because the pilot survey had shown that individual milling firms vary greatly with respect to such attributes as the power rating of the milling equipment, the degree of mechanization, and the type of service being offered. These three attributes were used as indicators of the level of differentiation or stratification. To permit economies and to ensure proper representation of each category of firms, firms were stratified into three groups: household, custom-milling firms, and merchant-milling firms. The following were considered to be the specific salient characteristics of each sample stratum:

- Household mills employ mainly either hand grinding or manual mills. It is primarily a manual activity, noncommercialized, and confined to serving the household economy;
- Custom mills operate hammer or small steel-cylinder technology. Generally, custom mills serve customers who supply their own raw grains for milling at a fee; and
- Merchant milling is dominated by roller-mill technology. Compared to the hammer mill, roller technology is more mechanized. Merchant milling involves the purchase of grains either directly from the farmers or through the state marketing institutions. Products from merchant mill are produced in a packaged form and sold through wholesale or retail outlets.

Sampling frame

Data generated by the pilot survey were supplemented by secondary data to form the basis for the sampling frame. Secondary data were gathered from the Cooperative and Rural Development Bank (CRDB), the Christian Council of Tanzania (CCT), Small Industries Development Organization (SIDO), Bureau of Statistics (list contained in the *Directory of Industries, 1971 and 1979*), Registrar of Industries, Tanzania Industrial Studies and Consulting Organization (TISCO; list contained in the *Industrial Directory, 1983*), Centre for Agricultural Machinery and Rural Technology (CAMARTEC), and the Marketing Development Bureau (MDB). A list of 305 milling establishments was thus compiled.

In the case of merchant roller mills, the population to be studied was very small (six mills for maize and five for rice); therefore, known and registered firms were surveyed. Proportionately, merchant roller mills were overrepresented in the sample. Maize merchant mills also employed six hammer mills. Only those (two) with rated output capacity of not less than 1 tonne/hour were included in the survey.

For custom mills, a multistage sampling was adopted. First, mills were classified by rural and urban locations and then by activity type (i.e., maize or rice). Then a purposive sampling procedure was undertaken to select 70 firms. The criteria for this judgmental selection were two-fold:

- Did the establishment possess sufficient particulars (e.g., clear address, location, and type of milling activity) to be identified unambiguously? and

- Was the establishment easily accessible by road and was located within 50 km of regional headquarters (to avoid logistical problems and excessive transport costs)?

On this basis, 70 milling establishments — 40 in urban and 30 in rural areas with 52 for maize and 18 for rice — were initially identified for the intensive survey. Because the mills selected were located in 10 different regions (ecological and cropping) — Arusha, Coast, Dar es Salaam, Dodoma, Iringa, Kagera, Mbeya, Morogoro, Mwanza, and Shinyanga — the sampling method adopted would tend to minimize the influence of resource endowment, thus making the sample more national in scope.

From the pilot survey and other secondary data sources, it became apparent that it would be operationally difficult to identify the location of manual mills. For instance, in the Arusha region, four out of five hand-mill operators who were to be covered during the pilot survey had migrated to other villages. It was then decided to exclude manual mills in the main analysis of this study on both operational and analytical considerations. Operational because of its somewhat "informal" character and hence the difficulty involved in obtaining accurate data; and analytical because, unlike merchant and custom milling, manual milling is never practiced commercially. The basis for comparative analysis appears, in this case, hard to justify. Indeed, as is shown later, even at the household level, manual milling methods are rapidly giving way to commercialized mechanical milling. They do not, therefore, seem to represent a real alternative to other methods.

Intensive field survey

The 83 selected custom merchant-milling establishments were then subjected to an intensive (micro level) survey using a pretested questionnaire. In summary, the questionnaire included five groups of questions:

- General information, e.g., name, address, location, ownership, etc.;
- Plant characteristics, e.g., type, model source, capacity size of plant, etc.;
- Sources and structure of capital;
- Input and output structure; and
- Factors influencing choice of technology.

The questionnaire, which was not precoded, was administered through face-to-face interviews. Within each firm, those interviewed included proprietor or manager, personnel officer, accountant, head miller, and chief mechanic. However, because some of the data required was historical and because several people had to be interviewed within the same firm, a cost-route approach had, at times, to be used. Multiple visits had to be made where data could not be ascertained easily and readily on the spot.

Major variables

Because several qualitative and quantitative variables are involved in this study, it is useful to mention at least briefly the measurement of the major variables, i.e., output, material input, capital, and labour.

Output

Output is defined and measured conventionally. Two types of data were collected on output: monetary and physical (tonnes) values. A firm's turnover is defined as its gross output value and is valued at the sales price (i.e., Tanzanian shillings). Value added (monetary) is then derived as the difference between a firm's turnover and its total material input values (see below). In the production function analysis and most of the subsequent calculations, the physical measure of output was preferred to the measure. This is deemed convenient particularly when firms produce a near-homogeneous output.

The physical measure also avoids some of the weaknesses associated with monetary value added. For example, variations in input and output prices arising from market imperfections may affect monetary value added that reflect elements of monopoly rent rather than the actual physical contribution of the primary inputs. It is also difficult to get complete and accurate data on all inputs involved in the production process. The physical measure may, however, face operational difficulties where joint products are involved.

Material inputs

Material inputs include raw grains, packing materials, and fuel and are measured in monetary values and reflect the purchase or expenditure value of the specific input category.

Capital

In this study, capital is divided into components of fixed and working capital. Fixed capital is defined to include equipment (tools and machines) and building. Controversy and debate surround the theoretical definition and measurement of fixed capital.

In our case, the difficulty of measuring capital has been compounded by three factors. First, milling equipment in use was built in different years. Different installations may thus differ from one another because of technological change embodied in newer equipment. Second, different milling equipment may have been bought from different sources at different prices. It is possible that price differentials may not be a reflection of differences in durability, sophistication, and other performance characteristics, but may be because of market imperfections. Third, for future expansion plans, replacement cost estimates, which if available would have been ideal, are totally missing for almost all custom mills. In a few merchant mills where book values were available, they could not be easily compared because of differences in asset lives, accounting procedures, and frequent asset revaluations. Indeed, it was not uncommon to find a written-off asset still in operation.

In the absence of replacement cost data, a proxy for replacement value was used. Initially, fixed assets were valued at their original cost (purchase price plus cost of installation) on the basis of information generated by the survey. Then, a price index is used to bring the initial acquisition cost value up to 1983 cost level. The resulting proxy for capital stock could only be valid if all capital stock components were of the same durability and vintage. Consequently, this capital stock measure was then converted into an annual capital (flow) charge by using the capital recovery (annuity) formula.[1] Working capital has been defined to include inventory of material inputs, work in progress, finished output, and cash — data on receivables are hard to come by: in any case, for custom mills, this item is assumed to be insignificant.

Because values on opening and closing inventory levels were missing, particularly for custom milling firms, components of working capital have been estimated on the maximum holding time of each stock for each firm.

Labour

Information on both stock (i.e., number of workers and wage bill) and service flow (hours worked) were gathered. For analytical convenience, workers have been grouped according to a three-way typology: operatives versus nonoperatives, skilled versus unskilled, and family versus hired labour.

Operatives are defined to include all directly productive workers engaged in plant operation, maintenance, materials handling, and packaging. Nonoperatives include managerial, secretarial, and clerical staff and overhead labour such as messengers and watchmen. Skilled labour refers to workers who have attended any technical or vocational school: primarily head and shift millers, mechanics, electricians, and rollermen. Most of the unskilled staff carried out auxiliary jobs such as loading, unloading, transferring of bags from conveyors, cleaning, and repairing empty bags.

In most of the subsequent analyses, employment data are corrected for casual and seasonal labour variations. The wage data were also used to cross-check the division of labour into skilled and unskilled tasks.

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[1]The total costs of a project consist of an initial outlay (P), i.e., the (undepreciated) original investment at a given date, and a further series of annual outlays ($C_1, C_2, ..., C_n$) throughout the project's useful life. Now, if the project lasts for n years and the rate of discount (r) is known, the initial investment (P) can be converted into a series of equal annual quotas (constant annual capital service flow — R) by the method of uniform annual equivalent standard costs or the annuity formula, i.e.,

$$[1] \qquad R = P[r(1+r)^n]/(1+r)^{n-1} = P(crf)$$

where crf is the "capital recovery factor" and may be interpreted as the proportion of initial investment that must be recovered in each period of asset life to equate the present value of the cumulative depreciation reserve with the initial investment outlay. This is clear if it is observed that:

$$[2] \qquad P = R(1/crf) = R(pwf)$$

where pwf is the "present worth factor."

Data limitations

The initial intention was to obtain historical data (as far back as possible), particularly on the evolution of the major variables. However, difficulties soon became apparent because of missing or obviously erroneous data. Therefore, observations had to be limited to 2 consecutive recent years — 1982 and 1983. Even then, some of the custom mills surveyed had incomplete or inconsistent data and were excluded. Thus, out of the 83 mills surveyed, only 65 have been retained.

Capital data gave some problems, too. For equipment, where our interest was on the acquisition cost, it was relatively easy to obtain such data as most operators kept purchasing records or at least could recall the figure roughly. Building cost caused the most trouble. This was so particularly among custom-mill operators because few of them kept records on cost of building. In such cases, the interviewer had to use a probing technique to guide the operator to arrive at an estimated cost.

In a few cases, the age of the enterprise was difficult to ascertain as ownership had changed hands several times. In such cases, age of enterprise under current ownership was taken as proxy measure for age (in years). Other conceptual and measurement problems are commented upon under the relevant sections of this study.

The study was, thus, very much conditioned by the type of data generated during the survey. One of the major shortcomings of these data is the lack of time-series observations. This makes it impossible to construct a complete production input–demand and output–supply system and has forced me to rely on single-equation estimation methods.

Analytic methodology

In testing the major hypotheses of this study, both qualitative and quantitative methods were employed. First, a qualitative analysis of the structure and historical development of the grain-milling industry in Tanzania was undertaken. This was believed useful in revealing the direction to which institutional factors such as product characteristics, policy-maker influences, and market forces bias decisions on technology choice. Much of the evidence reported here is of an anecdotal type, being mainly derived from secondary data sources and random survey responses.

In assessing the technology's economy in resource use, generation of potential economic opportunities, and degree of factor intensity, mean (weighted) input coefficients and factor ratios have been used. Additionally, project-appraisal methods have been applied to assess the private and social returns to the proprietor and, hence, the economic feasibility of a given technology. Second, to reinforce the utility of the qualitative analysis and to test the statistical reliability of the main results, a quantitative approach is used. This approach, which is achieved through a simple model designed within the neoclassical context of production-function analysis, also permits us to investigate the returns-to-scale and factor-substitution possibilities. The salient aspects of this model are described in Appendix I.

Chapter Four: Evolution and Structure of the Grain-Milling Industry

Technology available today is the consequence of the historical process in which technology evolved (Stewart 1977:9). Although science acts as the seedbed of technical innovation, it is the economic and historical circumstances that mould the particular characteristics of the new technology. These circumstances may either be institutional (i.e., the way production is organized and managed and the manner in which output is marketed) or technical (e.g., material input requirements, various production processes, and related infrastructural services). In this chapter, the manner in which institutional factors condition the nature and type of technology in use is investigated.

Institutional setting

Until the mid-1930s, the bulk of wholesale and retail agricultural trade, finance, agroprocessing, and transportation were handled by the private sector. Although the export–import agricultural trade was monopolized by European oligopolistic merchandising firms — for example, sisal was handled by the London-based Ralli Brothers, cotton by Tancot Ltd (which later became part of the Lonrho Group), and meat products and pyrethrum by Mitchell Cots and Liebeg Extract of Meat Company — internal agroprocessing and distribution were handled mainly by Asians. This arrangement rendered the African producers, particularly the small-scale farmer (or peasant), vulnerable to exploitation as they lacked any form of countervailing power to defend their interests (Rweyemamu 1973:33).

In the wake of the 1940s, however, private-sector dominance over internal agricultural trade began to be challenged. Two main agents of change were responsible for this challenge. First was the spontaneous and voluntary cooperative movement that began to emerge, particularly in areas where African peasants produced large surpluses of export crops (e.g., coffee in Kagera, Kilimanjaro, and Mbeya; cotton in Mwanza and Shinyanga; and tobacco in Tabora). The cooperative movement's primary intention was, in part, to check the perceived exploitation of the peasants by Asians. It was also partly a reflection of nationalistic sentiments: a desire by African peasants to assert their economic independence from colonial rule.

The second threat to private-sector control, particularly in foodstuff trade, came from colonial administration. The colonial government introduced a produce policy, under which the pricing, distribution, and marketing of staple crops were controlled by the colonial Department of Economic Control. This was implemented through issuance of various produce ordinances and the subsequent establishment of the Grain and Storage Department in 1949. Apart from having a monopoly in purchasing and marketing of food crops, this Department was also to ensure provision of storage facilities for holding working- and surplus-food stocks.

Colonial produce controls, however, affected only the pricing and distribution functions of the foodstuff market. The milling function, continued to be dominated by private millers — the leading private millers at that time included Tanganyika Millers Ltd, Chande Industries Ltd, Pure Food Products Company Ltd, Nur Mohamed Jesa and Company Ltd, Rajwani Mills Ltd, Mwanza Associated Traders Ltd, and Kyela Sattar Rice Mills Ltd. Furthermore, it should be noted that government intervention at the time was not intended to eliminate private traders as such. Rather, it was prompted by the desire to rationalize the food trade so as to achieve food self-sufficiency internally and to build surpluses to meet postwar shortages in other countries of the Sterling Bloc. This explains why this policy was short lived. For, upon achieving food self-sufficiency in 1957, the produce-control policy was abandoned in favour of a free-market policy.

After independence (1961), the party and government, seeking to exert their influence, became increasingly involved in checking further advances of private-sector entrenchment in agricultural trade. A three-channel marketing structure was subsequently designed and strengthened — in the agricultural sector, the structure consisted of marketing boards at the national level, cooperative unions at the regional level, and cooperative societies at the village level. This structure gave the newly established (1963) National Agricultural Products Board (NAPB) monopoly powers in pricing and marketing agricultural crops. To encourage the development of the cooperative movement, NAPB appointed cooperative unions as agents with exclusive privilege (through their respective cooperative societies) in purchasing crops from peasants. Through this three-channel marketing arrangement, the government intended to eliminate private wholesalers, retailers, and brokers in agricultural trade.

However, the milling function and other food-processing activities still remained the monopoly of private enterprises. Within the spirit of the Arusha Declaration (1967), however, the milling function was also brought under state control. The eight major milling companies were nationalized: placed temporarily under NAPB until February 1968, when they were amalgamated to form the National Milling Corporation (NMC) — the eight firms were Pure Foods Products Ltd, Tanganyika Millers Ltd, Kyela Sattar Rice Mills Ltd, Nur Mohamed Jesa and Company Ltd, G.R. Jivraj Ltd, Chande Industries Ltd, Rajwani Mills Ltd, and Associated Traders Ltd. Initially, therefore, NMC was established primarily as a manufacturer, processor, and importer of agricultural products.

By the early 1970s, the cooperative movement had established itself firmly — both politically and economically — particularly in the cash crop-growing areas of the country. This, however, attracted attention from the party and government, which began to monitor and direct the hitherto spontaneous movement. As a first step, the government issued compulsory marketing orders that instructed that cooperatives be set up in those areas that had not developed them voluntarily. This move was intended partly to eliminate private traders and, partly, to achieve parity between the more advanced and the less privileged parts of the country.

Over time, however, it became obvious that the rural elite who controlled the cooperative movement were the primary beneficiaries (through corruption, fraud, and mismanagement of funds) of the system (URT 1966; Kriesel et al. 1970). This was seen as leading to increased social differentiation — an undesirable element that jeopardized the party and government's aspirations for rural equity. More important, however, was the realization that the rural elite who dominated the cooperative movement posed a potential challenge to local political control (Coulson 1982:148–125).

As a result, the newly established (1973) crop authorities eroded some of the cooperatives' jurisdiction over crop collection and processing activities. The NMC, for instance, assumed crop procurement from NAPB. Additionally, NMC was also given responsibility for managing the strategic grain reserve.

In May 1976, the cooperative unions were finally abolished. Their previous economic functions were transferred and shared among Crop Authorities, Regional Trading Companies, and District Development Corporations (DDCs). The primary cooperative societies, which had served as procurement points for the unions, were replaced by the newly established villages. These were legally instituted to act as multipurpose cooperative societies. It was during this wave of change that, in 1975, NMC's functions were expanded through enactment of a revised NMC Act and the dissolution of NAPB. The new functions of NMC were to include the purchase, distribution, and storage of all general grains and staples offered for sale. The new act thus gave NMC monopoly power over control of maize, rice, wheat, cassava, millet, sorghum, and beans. Under this legislation, no one other than NMC was allowed to transport or sell more than 30 kg of any one of these crops.

Although, officially, private trading in major agricultural crops has been prohibited, informal marketing channels continue to thrive. Indeed, official and unofficial prices for major food crops have differed markedly. Available evidence indicates that, for the 1979–85 period, both producer and consumer prices for goods handled by NMC for sale — maize, rice, wheat, cassava, and beans — were substantially (1.5 to 3 times) higher on parallel markets than when sold through official channels (Keeler et al. 1982; MDB 1983b; Maliyamkono and Bagachwa 1990).

Unfortunately, estimates of the magnitude of food crops that are marketed through the parallel market are not reliable. Those available, however, indicate that the magnitudes involved could be substantial. For example, Temu (1989) estimates that, between 1964 and 1974, about 70% of total maize produced was consumed on-farm, 10% was sold through official marketing channels, and the remaining 20% was sold through illegal private-market outlets. This shows that for each 100 kg of marketable maize surplus, about 67 kg was sold outside the official marketing channel. Estimates by Keeler et al. (1982) suggest that, on average, the NMC supply of food in urban areas was sufficient to meet between 70 and 80% of the urban food needs. The balance of 20–30% was met from parallel-economy markets and urban on-farm sources.

The proportion of maize marketed through food markets of the parallel economy has been found to vary substantially from year to year depending on the weather and level of official producer prices. A study by Odegaard (1985) suggests that, generally, 80–85% of maize production is consumed on-farm leaving a marketable surplus of between 15–20%. Odegaard found that, in a normal year, about 70% of marketed maize surplus is channeled through the markets of the parallel economy. However, when the harvest is bad, as in 1974–75, the proportion of maize sold outside official channels may rise to well over 90%. In contrast, in years of bumper harvest, such as 1977–78, it may fall below 50%. In another survey, Bevan et al. (1988) found that only 18% of crop sales were made outside the official market.

Much more consistent estimates of the distribution of production between on-farm consumption, official sales of NMC, and other outlets have been provided by the MDB. MDB uses crop production estimates provided by Kilimo's Early Warning and Crop Monitoring Project. Estimates on subsistence consumption and marketed production are based on the 1976–77 Household Budget Survey (HBS) and on the ongoing Kilimo research. These estimates, although useful, do not adequately account for postharvest losses and interyear carryover stocks.

According to MDB estimates, an average of 80% of maize production and 50% of paddy production are consumed on the farm. Out of 20% marketed surplus, only 5% of total production is sold through official marketing agents whereas the remaining 15% (or 75% of marketed surplus) is sold in the food market of the parallel economy. However, in years with abundant supplies (e.g., 1985–86), MDB estimates that the share of marketed maize production in total production rises from 20 to 25%. About 64% of marketed maize surplus (or 16% of total production) is, therefore, sold in the parallel economy market. Similar findings have recently been documented by Maliyamkono and Bagachwa (1990).

In view of this lucrative parallel market for grains, it is not surprising that NMC procurement of maize and paddy declined drastically in the early 1980s. For example, NMC's purchases of maize and rice in 1982–83 were only 49 and 45% respectively of the amount purchased in 1978–79. As a result, 70% of its maize meal (sembe) sales, 81% of rice, and 68% of wheat for the 1981–82 market year were based on imports (MDB 1983a: annex 1). Furthermore, higher levels of unofficial prices have not only caused a shift from official to unofficial sales but also a shift out of the export-crop production into food crops for the unofficial market (World Bank 1981:18). Consequently, the ability of NMC to provide enough food supply to satisfy urban and rural demands has been adversely affected. As is shown later, this has encouraged the development of the custom-milling system. However, the question arises, why is there such a lucrative parallel market for grains? According to MDB (1983b:1),

> These [parallel] markets exist because the official marketing system is incapable of clearing the market. At the official price, demand is far higher than supply. There has not been enough officially marketed food, even with substantial imports in the past decade, to meet demand and so consumers have had no choice but to seek alternative channels.

Elaborating on the failure of the official marketing system to clear the market, Odegaard (1985) points out such factors as:

- Declining real producer prices;
- Failure of NMC to collect grains from peasants promptly; and
- Extreme delays in making payment to farmers.

The imposition of road blocks between regions further interfered with the smooth flow of grains from surplus to deficit regions resulting in artificial scarcity in some consuming regions.

Milling technologies and practices

Two important issues emerge out of this discussion: one is analytical and the other, institutional. At the level of analysis, given that NMC inherited milling technologies already in use, it makes little sense to analyze technology-choice issues at the time of its inception. Rather, greater insight on the issue can be gained by investigating the pattern and nature of its technological choices when it was expanding its milling capacity.

At the institutional level, these organizational changes have created a three-tier structure of milling practices in Tanzania. Merchant milling, under which grains are purchased from villages and are then milled, packaged, and distributed nationwide, has remained the preserve of the parastatal sector. Custom milling, under which grains are supplied by subsistence consumers in turn for a milling fee, remains mainly in the hands of small-scale private operators. In household milling, particularly in the rural homestead, traditional methods of hand-grinding are still being practiced. The three milling processes are examined more formally below.

Household milling

Household milling is predominantly a rural-homestead activity operating on a family-subsistence basis. This milling practice normally uses traditional methods of hand pounding or hulling, stone grinding, or manually operated mills. Household milling is basically, a manual activity.

In the case of maize, hand grinding involves manual decobbing of maize, placing the grain in a wooden mortar, and, with a little water added, pounding it with a pestle. A flat basket *ungo* is then used and, through shaking and winnowing, grains are separated from peels (bran). Coarser grains are again put into the mortar and the process repeated several times. The immediate coarser product may be cooked as a mixture with beans *(makande)*. The finely sieved whole meal flour is used to prepare porridge (*uji*) or, more commonly, a puddy-like meal *ugali*.

Rice is hand hulled using a wooden mortar and pestle. As with maize, pounding may involve up to three people working simultaneously. After pounding, the rice is winnowed and the process repeated several times until a desirable level is achieved. Normally, rice is hulled raw. At times, however, it is parboiled before being dehusked. Parboiling involves soaking paddy in water overnight then boiling it, after which it is sundried.

Because of operational and analytical problems mentioned earlier, household milling practices have not been intensively surveyed in this study. The limited information on household milling is based on a very limited sample of 15 households covered during the pilot survey. In the case of hand pounding of maize, however, losses could be high. In fact, losses between 30–40% (implying an extraction rate of about 60–70%) were reported to be common, particularly where it involved complete removal of peels (bran), embryos (or germ), and some starch, leaving almost pure white starch. Furthermore, the removal of peels and embryos implies that the meal becomes deficient in oil and protein. Hand pounding is, in this sense, not only arduous but also wasteful.

One alternative to traditional hand pounding is the use of nonmechanical mills.

Two broad types of nonmechanical mills were identified during the pilot survey: hand mills and foot mills. Hand mills are operated through turning of handles by hands. One variant of hand mills (e.g., the German type) has a single handle and can be operated by one person at a time. Another one, such as the English "Atlas" type, has two handles. Milling is achieved as the fed grains are trapped and squeezed between the metal grinding plates.

The two types of foot mills found in use were those developed by the Tropical Products Research Institute of the UK. The mill is either fitted onto a bicycle with a stand support, or fitted onto locally made pedal units. The operation is carried out by rotating the pedals, which, in turn, rotate the single hammer plate. Rated capacity for nonmechanical mills vary depending on the size of the mill. Generally, capacity varied from 3 kg/hour (for the smallest Atlas — model 1) to 10 kg/hour (for the largest Atlas — model 2). Actual quantities milled tend to be higher for smaller and softer grains such as wheat, sorghum, and millet than with coarser and harder grains such as maize. Moreover, although finer flour can be produced by grinding the softer grains once or twice, at least triple milling and sieving (taking about 3–4 hours) is needed to get a reasonably fine maize whole meal.

Unfortunately, the exact size of the household milling subsector for the entire country is not known. According to the 1967–77 HBS data, about 80% of maize and 50% of rice are directly consumed by producers. Part of this is eaten whole (as is the case of maize), another portion is hulled or ground domestically using traditional methods, and the rest is milled by mechanized custom mills. In the absence of countrywide surveys, one can only speculate on the magnitudes of the different proportions. However, a recent study carried out at Gwaye Village in Dodoma District reveals that the proportion of grains ground domestically using traditional methods could be high in certain localities. For example, the same study found the proportion of domestically ground grain to be 78% of the total grain consumed by an average household. The proportion milled by custom mills was about 23% (Rain 1983).

Custom milling

The alternative to manual milling is to use the services of the nearest mechanical custom mill. In custom milling, grains are mainly supplied by subsistence consumers in turn for a milling fee. Occasionally, however, custom mills also serve petty traders who bulk the product and sell most of the grain processed in urban markets. In fact, some were found to have been contracted by the NMC to mill part of its procured grain. For maize, custom milling is done with a single-stage hammer-mill technology.

A hammer mill consists of a horizontal rotary shaft carrying rotating high-speed disks to which are fixed a number of hammer bars. The outer casing has a screen designed to regulate particles of the appropriate size in the lower part of the mill. Screens of different mesh sizes may be used to vary the maximum particle size but not the minimum. This gives the hammer mill its characteristic flexibility in milling different types of grains. Grains are fed into the mill through a hopper at the top. They are crushed by being squeezed between the hammer bars. The product is sucked through a cyclone (or simply by gravity) and discharged through one or two spouts at the bottom of the cyclone.

Hammer mills grind all the maize into a light brownish whole-meal flour commonly known as *dona*. The extraction rate is very high and ranges between 96 and 99%, with 98% being typical for the sample. The loss, mainly in form of flour dust, amounts to only about 1–2%. Almost the entire grain (including germ and bran components) is thus retained. An obvious advantage of hammer milling over hand pounding is that the relatively hard and tough peels of the bran and germ are thoroughly ground, broken up, and incorporated in the meal together with the starchy endosperm. Although this is important nutritionally, the presence of oil makes the flour vulnerable to becoming rancid.

Hammer mills are powered by either electric motors or diesel engines. All rural hammer mills covered by this survey (21) were powered by diesel engines. In urban places, however, electric-driven hammer mills predominated (14 out of 20 were electric). It is obvious, in this case, that the type of power available influences the decision to choose between electric- and diesel-powered hammer-mill technology. It is, therefore, only in electrified (urban) places where there is a real choice between electric and diesel power to drive a hammer mill.

Hammer mills on the market vary widely in size. For the sample, the hourly rated capacity output ranged from 250 to 1 000 kg of meal. Their power requirements ranged from 15 to 54 kg/hour per tonne of meal. Sourcing of equipment varied too. Import sources mainly include Denmark, Germany, the UK, and the USA. Originally, both the engine or motor and the main body of the mill were imported as a package. Now, the mill body is produced locally in four sizes: small size, with capacity to accommodate an 8–12 hp motor; medium size, 15–20 hp; standard size, 22–30 hp; and large size, 33–60 hp (1 hp = 74.5.59 W). Although all diesel engines are still being imported, local capacity now exists for assembling electric motors.[2] Of the 41 custom hammer mills surveyed, about 58% used locally made bodies in their mills. No doubt the development of a local capacity in the manufacture of hammer-mill equipment has widened the range of choice for this technology.

Generally, rice milling involves three distinct subprocesses. First, the harvested, threshed, and dried rice is treated to remove foreign particles such as soil, stones, etc. Second, the grain is dehulled to remove the hulls or husks. Third, the bran and germ are separated from the endosperm to produce white rice kernels. Additional stages such as polishing and glazing may be carried out in response to special market requirements.

In custom milling of rice, two types of mechanical rice mills were found in operation. One is the Engelberg huller, which consists of a steel, cylindrical, fluted roller revolving on a horizontal axis inside a sheath casing. Dehusking is achieved by the shearing action on the grain produced by the movement of the roller flutes past a stationary blade. As grains are squeezed against each other, both the hull and bran are removed achieving dehusking and polishing simultaneously. Total rice recovered ranged between 55 and 65% with 62–64% being fairly general.

The most common make was the British Lewis Grant rice mill (6 out of the 11 mills). Two McKinnon and one German Schule were also found in use. These mills

[2] A leading manufacturer of electric motors is Pioneer Electric Machines and Consulting Company (PEMECO) of Mbeya. Leading local mill manufacturers include Manik Engineering (Arusha), United Engineering Co. (Arusha), National Engineering Co. (Dar es Salaam), and Mang'ula Machinery Company.

were powered by 15–16-hp engines. Two small rubber-roller shellers were also found operating during the survey. The rubber-roller sheller is a relatively modern technology developed by a Japanese firm, Satake. It has two closely spaced rubber rollers rotating in opposite directions at different speeds. As paddy is fed into the sheller, the grains are caught under pressure by the rubber and, because of the difference in speed, the husk is stripped off. Rice recovery of 64–66% has been reported.

The exact number and capacity of custom mills in Tanzania are not known. The World Bank (1981:5) estimates that about 66% of total commercial milling activities are carried out by custom mills and that also about 25% of the 8 000 registered villages in Tanzania have at least one maize or rice mill. There are indications, however, suggesting that the custom-milling subsector is not only relatively large but also expanding rapidly. For example, the total number of mills distributed by the Cooperative and Rural Development Bank (CRDB) — the former Tanzania Rural Development Bank (TRDB) — has more than tripled between 1977 and 1981. To a limited extent, this seems to suggest that demand for custom mills must have been expanding during this period.

Several factors seem to favour the expansion of the custom-milling subsector in Tanzania. In the first case, the penetration of mechanized custom-milling technology into the countryside has increased the range of choice of different grades of grain meals for the rural household. The rural inhabitant can now trade-off between meal produced manually or by a custom mill, or a packaged meal produced by a merchant mill and stocked in the nearby retail store. The actual choice will be influenced by a number of factors:

- Availability of cash;
- Time needed to obtain the meal;
- Arduous nature of the activity; and
- Social or habitual considerations.

Traditional methods of hand grinding are generally considered by many of the peasants interviewed as being extremely arduous, tedious, and unnecessarily time consuming. This problem is slightly eased if a household acquires a small manual mill. At the time of the survey, manual mills cost between 5 000 and 8 000 TZS (in 1983, the official exchange rate was 12.24 Tanzanian shillings (TZS) = 1 US dollar (USD)). Per-capita income was, at that time, about 2 200 TZS. Thus, the choice of purchasing a household manual mill or using the services of a custom mill can be considered as a choice between a capital cost and recurrent cost. Uhlig and Bhat (1979) equate this to a choice in an industrial society between the purchase of a washing machine and the use of a laundrette (laundromat in North America). Under such circumstances, an average peasant is likely to be constrained by capital funds when deciding to purchase a hand mill.

Other considerations may influence this decision apart from money costs. For example, when compared to traditional hand grinding, a manual mill will save little in terms of time and energy. Moreover, the activity itself is still arduous. With a hand mill, 10 kg of maize flour may be obtained after 3–4 hours of arduous grinding. According to our survey, the average time spent to pound 10 kg of maize by hand was about 6 hours.

Probably this explains why, during the second half of the 1970s, mechanized custom mills became a subject of many rural development initiatives. As one observer (CCT 1980:15) put it:

> In almost every village the first priority is to obtain a diesel grinding mill. It saves the womenfolk ... and children many hours of tedious and tiring work. Their readiness to walk for miles and wait for hours in queues is an indication of the value which they place on this saving.

For an average rural peasant, the custom mill is about 5 km away, which is about 2 hours walk there and back. If 1 extra hour is assumed to be spent while waiting for grain to be milled, this adds up to 3 hours per trip. Typically, 1 debe (about 20 kg) is considered the normal load of maize taken to be milled per trip. The equivalent time for hand pounding is about 15 hours. A simple calculation of the economic value of hand pounding maize using a shadow wage of rural unskilled labour results in a value of 1.35 TZS/kg as compared to 0.55 TZS/kg when milled by a mechanical custom mill.[3]

The alternative of carrying maize to the nearest mill is thus not simply a question of using time differently because less time is involved as compared to hand pounding. However, there is more in a custom mill than just energy and time savings. As one rural woman observed, when walking to the mill and while waiting for grain to be milled, "we [women] get an opportunity of exchanging views with one another. Besides, for us, it is like having a break." This aspect of social interchange that, in many rural communities, revolves around routine household tasks is an important consideration sociologically. An added flexibility of the mechanical custom mill is that, unlike the merchant mill, it can still provide the opportunity for such social interchange.

The high demand for the custom mill in rural Tanzania seems to have also been prompted by habit and the "engineering-man" complex in which civilization and modernization are conceived of as changes from manual to motorized technology. The origin of this habit can be traced back to the early 1970s when diesel was cheaper and foreign exchange more easily available. Subsequently, government and foreign donors responded quickly and positively by providing many villages with diesel custom mills. This habit now has to be sustained. In the minds of most villagers interviewed, manual mills are primitive and nobody likes to turn the clock back. One should also not forget that, on the supply side, investment in custom mills has probably increased with the spread of cheap hydroelectric power that allows greater profits to be made — the cost–benefit analysis in Chapter Five (*Utilization of resources*) clearly shows that electric-driven mills are cheaper to operate than diesel-powered mills.

These observations raise the question of social acceptability of technology. In the Arusha region, for example, the use of pedal mills was unpopular because women (who normally grind grains) traditionally dislike riding bicycles. Men, on

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[3]This is definitely a rough estimate as the parameters involved are not known with precision. Our investigations showed that hand pounding 1 kg of maize takes about 45 minutes. A monthly shadow wage for unskilled labour in rural areas is estimated to be 435 TZS (see Chapter Five, *Factor productivity*) implying an hourly rate of 1.80 TZS. Thus, the social cost of hand pounding 20 kg of maize is 27.00 TZS (i.e., 15 hours at 1.80 TZS), whereas the cost of custom milling 20 kg is 10.40 TZS (i.e., 3 hours at 1.80 TZS plus 0.2 TZS/kg as milling fee).

the other hand, felt it was degrading to get involved in what was, hitherto, traditionally considered as a women's activity. Besides, men saw the use of a bicycle in grinding as uneconomical and so took it off the mill and used it for other purposes (CCT 1980:13). This demonstrates that technology is not simply a question of tools and machines, nor just operational costs; rather, a particular choice of technology necessarily involves the intangible human element. To be operationally effective, therefore, technology should capture the cultural and social as well as economic needs of the users.

On the other hand, when compared to merchant milling, custom milling may be preferred by the rural consumer because it allows the consumer to carefully select the grain to be milled. This is important because the quality of raw grains determines the quality of output. Merchant milling lacks such versatility because grains are sorted by millers under standard conditions. Furthermore, grains milled by merchant mills tend to be less fresh.

Merchant milling

In Tanzania, merchant milling involves purchasing, milling, packaging, and distributing milled products by NMC. Grains are purchased either directly from villages or from other parastatal marketing institutions such as the National Agricultural and Foods Company (NAFCO). Distribution is carried out through wholesalers, e.g., National Distributors Ltd (NDL) and Regional Trading Companies, and directly to retail outlets.

In maize milling, NMC employs both roller and hammer mills. Roller mills produce sifted maize flour generally known as sembe. Typically, a roller mill consists of a series of machines that clean, condition, degerm, grind, sift, and classify output. The basic activity of grinding is carried out by rollers that rotate at different speeds in opposite directions. As the feed passes from one stage to another, a special device selects and separates the bran and germ fractions from the endosperm fraction. All rollers and accessories are imported.

Previously, roller mills were used to produce two types of sifted maize flour: sembe superior and sembe standard. Sembe superior is a fully degermed meal produced at 78–84% extraction rate. Sembe standard is partially degermed and is produced at an average extraction rate of about 90%. Since 1979, the government has imposed a ban on the production of sembe superior to encourage the consumption of sembe standard and whole-meal flour. This was done in view of the prevailing grain shortages in the country because the latter make better use of raw grains and are comparatively more nutritious.

For rice, NMC's merchant mills employ large rubber-roller mills. Rice is normally milled raw at an average extraction rate of 65%. There is little control for moisture and percentages of broken grain have been high (between 10 and 30%).

NMC's merchant milling capacity for maize, paddy, and wheat is shown in Table 2. Rated capacity for both maize and rice rollers range between 1 and 5 tonnes/hour. All rollers can be operated on a three-shift basis. At the time of the survey, NMC was operating 26 mills. Of these, 12 catered for maize milling, 12 for rice hulling, and the remaining 2 for wheat milling.

The corporation's nominal (installed) capacity for maize is estimated to be about

172 200 tonnes/year on a three-shift basis. Of this, the six roller mills could, if operated at full capacity, produce 113 300 tonnes/year and the six hammer mills could produce the other 58 900 tonnes/year. However, chronic mechanical breakdowns and problems with spare parts coupled with power-supply problems have resulted in low levels of capacity utilization. As a result, the effective capacity of both NMC's roller and hammer mills has been insufficient to cover current demand for maize flour. In turn, this has necessitated the contracting of private custom millers (Table 3). Thus, of the NMC's total annual sales of sembe between 1980–81 and 1983–84, about 41% was milled by private custom millers.

NMC has an estimated nominal rice-milling capacity of about 142 800 tonnes/year. This is believed to be more than necessary because over half of its domestic rice purchases and almost all its imports are in form of rice rather than paddy.

The existing wheat-milling capacity of about 96 000 tonnes/year is considered insufficient to meet current (1983–84) demand and an additional extension of the Arusha plant has been planned. This will provide an additional milling capacity of about 1 000 tonnes/day. Plans are also underway to rehabilitate the existing maize

Table 2. National Milling Corporation's (NMC) annual installed milling capacity by region (tonnes).[a]

Region	Maize	Paddy	Wheat
Dar es Salaam	65 400	68 400	75 000
Arusha	43 200	—	21 600
Mbeya	—	6 600	—
Mwanza	14 400	14 400	—
Dodoma	18 000	—	—
Iringa	15 000	—	—
Kigoma	9 000	—	—
Shinyanga	—	36 000	—
Morogoro	—	6 600	—
Kagera	7 200	—	—
Tabora	—	10 800	—

Source: NMC.
[a] Based on three shifts per day: as of December 1983.

Table 3. National Milling Corporation's (NMC) sales of sembe by source (000 tonnes), 1975–84.

Year	Total sales [a]	Output from NMC's mills [b]	From private hired millers [c]	Percentage of [c] to [a] [d]
1975–76	124	77	47	37.8
1976–77	121	100	21	17.4
1977–78	99	83	16	6.0
1978–79	141	101	40	28.4
1979–80	176	106	70	39.8
1980–81	224	128	96	42.9
1981–82	211	123	88	41.7
1982–83	170	100	70	41.2
1983–84	175	101	74	42.3

Source: NMC.

mills and to expand maize milling by building two roller mills with a capacity of about 180 tonnes/day.

At present, most of NMC's milling capacity is concentrated in consuming areas such as Arusha, Dar es Salaam, Dodoma, Iringa, Mbeya, Mwanza, and Shinyanga. The absence of milling capacities in surplus regions (such as Rukwa and Ruvuma) was defended by NMC officials on grounds of shelf life and transport costs. It is argued that resource site-based milling means that the milled flour must be transported to consuming centres. However, given the limited shelf life of the maize meal, this may be a serious problem, particularly when transport is unreliable. Moreover, the problem of weight for raw maize is reduced when maize is decobbed, cleaned, and dried before being transported to milling centres in the consuming areas.

An important point to note, however, is that both NMC's own and contracted milling capacities have been unable to meet the full urban demand for preferred cereals. Thus, for the period 1974–75 to 1979–80, NMC could only meet 72.8%, on average, of the urban food needs for the Tanzanian mainland. This average veils important regional variations, however. For example, it was 14% for Mbeya, 40% for Mwanza, and 80% for Dar es Salaam (Keeler et al. 1982). This suggests that, on average, 23–30% of urban food needs have been met by the parallel market. It also implies that, even in urban areas, a significant proportion of the population is served by custom mills. In other words, the inability of the merchant-milling subsector to meet urban food demand has definitely increased the demand for custom-milling services in urban areas.

Product characteristics

Characteristics of product quality enter directly and indirectly into the technology-choice decision matrix. Directly, because a given product may only be producible by a specified technology because of certain unique features. Indirectly, because the creation of consumer demand for product of a certain quality may induce investors to choose a technology that can best satisfy such a demand. Demand patterns are, therefore, potentially important because they influence the level of employment, output, and production technique. The nature of the product is an important direct aspect of appropriate technology. In particular, there is strong presumption that small-scale and labour-intensive production techniques are associated with appropriate products, i.e., products that are compatible with the income levels of most of the population. On the other hand, capital-intensive techniques produce high-quality products that only a high-income minority in the society can afford (Stewart 1987).

In grain-mill products, quality differences are apparent in colour, granularity, nutrient composition, and shelf life. A typical longitudinal structure of maize kernel has three distinctive parts. The bran is the outer thin, fibrous casing that makes up about 12% of the kernel weight. Beneath it is the starchy endosperm — about 82% of the kernel weight. The innermost part is the germ, which contain 35% of oil and accounts for the remaining 12% of the kernel (Uhlig and Bhat 1979:19).

The extent to which bran and germ are separated from the endosperm part of the maize grain defines the differences between the three types of maize consumed in

Tanzania, i.e., sembe superior, sembe standard, and whole meal (*dona*). As mentioned earlier, the unsifted whole meal is produced by grinding the whole maize including the germ and bran at an average extraction rate of 98%. The remaining 2% is a milling loss caused by reduction in moisture content and spillage in the mill. Sembe standard is extracted at 90% and almost half of total bran and germ contents are separated from the endosperm. The extraction of sembe superior, at about 80%, removes almost the whole germ and bran fractions.

Thus, the sifting process of the roller mill affects the quality of the maize flour and reduces the nutritional content of maize (Table 4). The most-sifted sembe superior is, on average, less nutritional than the unsifted whole-meal flour. The absolute reduction of protein is of real concern because, of the three types of proteins contained in maize — zein, globulins, and glutelin — the latter two better types are removed leaving zein, which is a poor source of protein (Stewart 1977:212).

The three types of maize also differ as to their granularity, colour, and storability. The sifted flour has a finer, more even granularity and is whiter than the whole meal, which has a relatively higher fat content (about 5%) and is also more vulnerable to becoming rancid and, therefore, has a shorter shelf life than the sifted flour. NMC experts indicated that, if properly stored, the fully sifted sembe superior could last as long 12–18 months whereas sembe standard could last from 6–10 months. On the other hand, the whole-meal flour may turn rancid in less than 1 month. This limits its marketability and ties custom mills to local markets. Officials at NDL (a wholesaler) agreed that the whole-meal flour has a much shorter shelf life, but indicated a much shorter maximum (6 months) for sembe standard.

There was also unanimous agreement among millers and a sample of consumers interviewed that the unsifted whole-meal flour needs longer cooking than sifted meals. The actual cooking time depends on several factors, including: type of cooking utensil, type of fuel used, room temperature, and style of cooking, particularly the amount of water used.

Under controlled conditions, however, the whole-meal flour takes 2–4 minutes longer to cook than the sifted meal because it contains the fibrous parts of the bran,

Table 4. Nutrient composition of different maize meals (per 100 g of flour).

	Fully sifted meal (sembe superior)[a]	Partially sifted meal (sembe standard)	Wholemeal (dona)
Calories	363	360	356
Protein (%)	8.4	9.3	9.5
Calcium (mg)	5.0	6.0	7.0
Iron (mg)	1.2	1.8	2.3
Thiamin (vitamin B_1) (mg)	1.18	0.09	0.45
Riboflavian (vitamin B_2) (mg)	0.08	0.09	0.11
Niacin (mg)	0.6	1.3	2.0

Source: Uhlig and Bhat (1979:18).
[a] Names in parentheses are Tanzania meal equivalents.

Table 5. Nutrient composition of different rice grades.

	Brown rice (with bran)	Raw rice	Parboiled rice
B vitamins (µg/g)			
Thiamine	4.2	0.8	2.27
Niacin	18.1	39.8	47.2
Pydridoxine	10.3	4.5	4.5
Pantothenic acid	17.0	6.4	—
Riboflavin	0.53	0.26	0.36
Protein (%)	8.3	7.6	7.8

Source: ILO/JASPA (1981:22, table A).

which takes a bit longer to boil. Costs of such extra time are crucial in influencing demand conditions, particularly where working urban consumers are involved.

As in maize, quality characteristics in different rices give rise to different demand conditions. Structurally, rice grain is encased in a protective spiny husk. Within the husk is the kernel of the brown rice. The outermost part is the pericarp and acts as a barrier to rancidity. Beneath the pericarp is a seed-coat layer, the bran, that in turn surrounds the starchy endosperm and the innermost oily germ or embryo. In paddy grain, about 72% is comprised of the endosperm, 20% husk, and about 8% bran (ILO 1981:21).

Two major types of milled rice are consumed in Tanzania: raw or polished rice and parboiled rice. Raw rice is obtained by removing the husk by dehusking and the bran by polishing. Before dehusking, paddy may be parboiled to produce parboiled rice. Parboiling, whether carried out mechanically or manually, involves prior saturation of paddy with water, then raising the temperature to the boiling point after which the paddy is sundried before being dehusked. This process, by fusing the starchy molecules, enhances the toughness structure of the rice grain and makes it more resistant to shattering during milling. Consequently, the proportion of broken kernels in the milled product are lowered and the yield improved. The nutritional value also increases as the boiling process facilitates penetration of vitamins from the surface coating to the interior of the kernel. Apart from quality of paddy and degree of polish, the parboiling process has an important influence on the nutrient composition of rice (Table 5).

Markets and products

Under competitive market conditions, one would expect the miller to choose the grade of product to produce on the basis of expected profitability, tastes, and preferences. Markets are not only important in determining the type of product being produced but also the scale of production. Within the domestic economy, certain markets cater largely for high-income groups and others for low-income consumers. In general, low-income consumers require a less sophisticated and "lower quality" product, typically produced by small-scale labour-intensive technologies. On the other hand, "higher quality" products are more in demand among high-income consumers and are associated with more capital-intensive technologies (Stewart 1987; Stewart and Ranis 1989).

However, government intervention may limit the miller's choice of products, thereby, interfering with the consumer's sovereignty. For example, by according NMC a statutory monopoly power over merchant milling, the government has limited the private miller's choice of technology. The fact that private millers are not allowed to distribute milled products implies that they can only operate on a custom-milling basis. This ties them to the neighbourhood markets. Given the constraint of market size, it is natural to expect private custom millers to operate on a small-scale basis. This is one of the major reasons why 78% of the custom maize mills surveyed operated hammer mills with capacities of less than 0.5 tonne/hour. It also explains why about 52% of the mills operated several, but widely spaced, units simultaneously. The spreading of the milling unit is intended to take advantage of the limited neighbourhood market. Government policy has thus, circumscribed the miller's choice of technology.

Consumer tastes have also been directly influenced by government pricing and subsidy policies. Up to 1983, government maintained a 55% explicit subsidy for sembe produced by NMC. Custom-mill operations in both urban and rural areas were not being subsidized. This decision was taken to ensure an adequate supply of maize and to protect the real purchasing power of urban wages (MDB 1983a). However, a side effect of this was to discourage the expansion of custom mills whose products became relatively expensive.

The consumer's choice of product has also been affected by government policy of quantitative controls. The restriction on the production of sembe superior is a case in point. In urban areas, most of the consumers interviewed randomly indicated a strong preference for sifted maize meals when they were available. They would buy the unsifted whole meal because it was the only choice offered. This was also the opinion of the five NMC branch head millers interviewed.

However, the government's ban on the production of the fully degermed sembe superior can be defended on the ground that it was an inappropriate product. In the first case, of the three meals, sembe superior has the least nutrients; second, it was being produced by a less appropriate technology; and, lastly, most Tanzanian (low-income) consumers could not afford it. Before it was banned, sembe superior used to sell at twice the price of sembe standard and 2.3 times the price of the whole meal. Sembe superior was thus a luxury commodity consumed mainly by the few high-income groups in urban areas. On the other hand, one would not regard sembe standard as a luxury. First, although in this case it was being produced by a less appropriate technique, it could, in principle, be produced by a hammer mill if accompanied by a sifting device. Second, random consumer interviews showed that more than 80% of the consumers who bought the whole meal from retail stores normally sifted it (almost to an equivalent sembe standard) before cooking. Lastly, although the price of sembe standard was about 28% higher than the price of maize whole meal produced by NMC (before the subsidy), it was almost at par with the (imputed) price of a whole meal produced by custom mills.

From consumer survey responses, it would appear that, when the supply of food grains is not constrained, the substitute for sifted maize meals in urban areas is not the maize whole meal but rice and bread.

In urban areas, the preference for the fully sifted maize meals is mainly a result of distorted tastes and preferences. The sifted flour is finely milled, looks whiter, tastes sweeter, and lasts longer than the whole meal. This outcry for high-quality products has led to the use of inappropriate techniques. This has been inevitable because high-quality products reflect demands by high-income societies and are normally produced by new, capital-intensive machines. The sifted meal, for example, is very much a child of technological development of the 19th century. The modern multistage roller mill "was thus a case of technical progress that was essentially directed at product innovation rather than at cost reduction for a given product" (Uhlig and Bhat 1979:xvii).

Sifted meals were introduced in Tanzania in the early 1950s after becoming "successfully" popularized among the Kenyan elite. Before private mills were nationalized (1967), the fully sifted sembe superior was mainly promoted through advertisement and fine packaging. Thereafter, with NMC assuming monopoly powers over production and distribution of milled products, advertisement became less important as the market was more or less guaranteed. Nevertheless, the seeds for imitative patterns of consumption that favour high-quality products had already been sown. Indeed, as other case studies have shown, it is now established that product quality has become an important determinant of technology choice in Tanzanian industry (James 1983, 1987; Alange 1987)

On the other hand, the rural peasants have their own supply of grains and, for them, time may be relatively less costly compared to the urban counterpart. Furthermore, in certain rural areas, the retail store stocking sifted meals may be distantly located. There is, thus, a strong preference for the unsifted maize whole meal. The limited life of the whole meal is not really a problem here because a peasant would normally take a small quantity of maize to be milled at a time. The taste of the whole meal can also be improved by the consumer through careful selection and prior treatment of grain before taking it to the miller.

Clearly, from the point of view of consumers, custom and merchant mills produce products that differ in terms of quality, provision of consumer satisfaction, and service characteristics. Ideally, comparison of substitution possibilities between firms should be made when the final product is a close — in theory a perfect — substitute. The notion of a "close" substitute is of course a relative one. Some authors have argued that, when considering technological options available, the product in question should be defined more flexibly and should not be constrained by the question of close substitutes (Stewart 1977; Nihan et al. 1979; Baron 1980). They reason that restricting the analysis to close substitutes would tend to exclude some of the simpler techniques and products from the market. However, even when the analysis is confined to close substitutes, this does not rule out some degree of product differentiation.

An important observation emerging out of the previous analysis is the sensitivity of technology to product characteristics and market organization. Traditional milling methods and manual mills cater almost exclusively to the household subsistence sector. Custom-milling technologies serve neighbourhood markets in rural areas, small towns, and low-income urban areas. Large merchant roller mills' products are distributed nationwide but cater mainly to urban consumers. Different technologies thus cater to different segments of the market. In the case of maize, the choice of a maize meal implies choice of a particular type of technology. For example, it is operationally difficult for a custom hammer mill to produce a sifted meal. Technically, effective production of sifted meals requires the use of special devices to control particle size — such as the degermer or cylindrical rolls that are lacking in the hammer mill. Also, although it is technically possible to operate a maize roller as a custom mill, it is not economically feasible to do so. The limited size of the custom-milling market precludes its use on the grounds of relatively high capital and operational costs. For equipment designed to operate on a three-shift basis, it is more likely that excess capacity will result if a roller mill operates as a custom mill. In general, the choice of product mix and of mill specification appear to be inextricably intertwined. Moreover, to the extent that custom and merchant mills cater for different groups, sectoral bias of policies will have important income-distribution implications.

Macro policy environment

Government penchants for direct intervention and controls extend beyond the specific micro policies directed at the grain-milling industry into the economy-wide policies that have had important indirect impact on the operating environment of grain mills and other aggregates of the economy. In principle, the government can influence decisions on choice of technology through policies that affect the firm's objectives, accessibility to resources, technology availability, and markets. In what follows, I attempt to investigate qualitatively the impact of the major policies that influence the price and availability of resources facing microenterprises in general and, by implication, grain-milling firms.

The major policy impacts are explained from three perspectives. First, the domestic capital market has been heavily subsidized by the high rates of domestic inflation. The banking sector in Tanzania is exclusively government controlled. Accordingly, interest rates on loans and the structure of loans are controlled by the government through the (central) Bank of Tanzania (BOT). Credit allocation is also carried out quantitatively according to government policy priorities as specified by the Finance and Credit Plan.

Although this arrangement is intended to channel credit to the "high priority" sectors, it has had two undesirable side effects. One is that credit rationing has led to the bulk of loanable funds being allocated to the large-scale public-sector firms that are both the most politically and economically adept of the eligible recipients. The small-scale sector, which is predominantly privately owned, has thus been discriminated against in the institutional market for credit on the grounds of higher risks and administrative lending costs. These reasons are usually attributed to their wide geographical dispersion and lack of collateral.

This has been the case despite the current policy initiative of the government to redress this bias by creating additional public-lending institutions, e.g., the CRDB, and by reserving a portion of the loan portfolio of the National Bank of Commerce (NBC) for the use by small enterprises. A program of guaranteeing a portion of bank loans to small enterprises by the BOT has also been approved in principle but is yet to be implemented. The credit bias is reflected, for example, by the small share of small-scale industry (SSI) loans in total CRDB loans, which averaged 5.7% per year between 1976–77 and 1986–87 (Table 6). Even NBC's share of SSI loans in total NBC approved loans stood at a relatively insignificant level of 0.57% in 1986–87.

Moreover, to the extent that credit policies have resulted in interest rates that are below the opportunity cost of borrowing domestic capital, they have, as a second

Table 6. Share of small industry (SI) loans in total Cooperative and Rural Development Bank (CRDB) and National Bank of Commerce (NBC) loans (TZS million), 1976–77 to 1986–87.

	CRDB			NBC		
Year	Total lending	SI loans	SI as % of total	Total lending	SI loans	SI as % of total
1976–77	77.3	2.4	3.1	4164.9	1.0	0.02
1977–78	247.0	1.7	0.7	5789.7	11.3	0.19
1978–79	187.8	11.3	6.1	6284.0	10.4	0.16
1979–80	207.9	12.0	5.8	6921.9	6.3	0.09
1980–81	101.2	10.8	10.7	8074.2	4.7	0.05
1981–82	263.4	17.0	6.5	8861.3	13.7	0.15
1982–83	207.1	15.0	7.3	7798.0	22.9	0.29
1983–84	147.5	23.5	16.0	9095.0	69.5	0.76
1984–85	460.8	16.1	4.0	12322.8	220.8	1.79
1985–86	1236.1	4.3	0.3	17320.1	139.9	0.81
1986–87	1967.7	42.6	2.0	39343.6	224.3	0.57

Sources: CRDB and NBC.

side effect, biased choice of technology toward greater capital intensity. The BOT, which maintains ceilings on deposit rates as well as floors and ceilings on commercial lending rates, maintained fixed nominal interest rates between 1966 and 1984. Thus, for example, the effective lending rate remained fairly constant, increasing from an average of 8.5% in 1966 to about 10.3% in 1982. At the same time, prices rose at an average annual rate of about 5% per year up to the mid-1970s but rose four times as much between 1979 and 1985 as measured by the National Consumer Price Index (NCPI). Thus, the real cost of borrowing for investment has been declining over time.

Similarly, a significant amount of foreign-capital inducement has also been subsidized directly by government policy and indirectly by domestic inflation. For example, interest rates on foreign loans have been extremely low, averaging between 1.1% in 1970 and 2.2% in 1981 (World Bank 1983). These figures are not only far below the domestic rate of inflation but also quite below the domestic lending rates. The latter aspect may bias savers toward import-intensive investments. Thus, on the whole, both domestic and foreign loans revealed negative real rates of interest implying that funds for domestic and foreign capital formation were supplied with almost no interest.

From the second perspective, the Tanzanian labour market has been very rigid. Rigidity has taken a form of minimum-wage legislation, mandated fringe benefits for middle to senior parastatal and government workers, and the government's directive that restricts the authority of entrepreneurs and other employers to lay off workers even during a recession. Although real wages in Tanzania are depressed, and in many instances skilled workers are very scarce, there is a high degree of overstaffing given the low levels of capacity utilization. These aspects tend to make labour artificially expensive (relative to capital) and may inhibit the expansion of employment.

Third, distortions have arisen from government intervention in the foreign-trade regime. Up to 1984, the foreign-trade regime in Tanzania employed a rationing system for all essential imports (in conformity with the Foreign Exchange Plan) and were characterized by an overvalued exchange rate.[4] These two policy aspects would tend to favour large-scale public enterprises that can exercise political and economic power (Wangwe and Bagachwa 1988). Because direct allocation of import licences tends to favour large-scale firms, the structure of protection provides an implicit subsidy to direct large-scale importers.

The end result of such policies has been the cheapening of rental values relative to the price to labour. As White (1978) notes, the outcome of such policies has two consequences. First, the relatively high cost of labour will tend to curtail its employment in the short run; and, second, it will give rise to substitution of capital for labour in the long run. Although it has not been possible to establish the exact magnitude of such policy impacts, because other factors must have been at work,[5] the general trend is that of growing capital intensity over time as revealed by the rising capital–output ratio and the incremental capital–output ratio (ICOR) for the manufacturing sector as a whole. For example, in 1980, the ICOR was eight times higher than in 1970 (Kahama et al. 1986:81). By implication, the macropolicy environment in Tanzania has tended to work in favour of the large-scale merchant-milling sector and to discriminate against the development of the custom-milling sector.

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[4]For example, Lane (1984) casually reports that the 1983 black-market rate was 60–70 TZS/USD while the official exchange rate stood at 12.24 TZS/USD. Several authors have unanimously noted that the Tanzanian shilling is over valued (see, for example, Lane (1984), Naho (1986), and Ndulu and Lipumba (1986)). They differ only as to the extent of overvaluation. Because these authors use the purchasing-power parity method to estimate the extent of overvaluation, some of the differences can be attributed to the choice of different base years at which the exchange rate is assumed to have had a parity value. See Odegaard (1985) and Maliyamkono and Bagachwa (1990) for detailed discussion on the causes and extent of the overvalued exchange rate in Tanzania.

[5]Two other possible factors could have contributed to the rise in capital intensity in industry. One is a shift toward heavy investments that have long gestation lags undertaken to meet demands of some of the projects under the Basic Industry Strategy. However, prevalence of excess capacity could also be another important factor.

Chapter Five: Technology and Resource Use

The previous chapter focused on the roles played by product quality characteristics and the way in which markets are organized in determining technological choices. Technologies, however, are not only designed to produce a product that satisfies a particular pattern of demand, but also they are developed in conformity with a particular set of input requirements. Thus, the supply — in terms of both quality and quantity — of a particular set of inputs and the manner and level at which they are used constitute an important aspect in determining technology choice.

This chapter examines some of the key supply factors that play crucial roles in determining the composition of milling technologies in use. The important supply issues relate primarily to the intensity and effectiveness with which milling establishments use their economic resources. Specifically, the analysis centres on factor intensity, factor productivity, and surplus generation. An important related demand issue that is also discussed is the extent of consumption and production linkages. First, however, the sample firms are briefly described in terms of location, employment, and capital structures.

Sample firm characteristics

Location and ownership patterns

Small-scale custom mills (those with output less than 24 tonnes/day) were found in both rural and urban areas (Table 7). They were primarily (83%) owned by individual proprietors: partnerships and village cooperatives were extremely limited. On the other hand, merchant mills with capacities of at least 24 tonnes/day were confined to urban areas and all were owned by the National Milling Corporation (NMC). It is obvious from the earlier discussion that the locational pattern of different mills closely follows the urban–rural demand patterns for their products.

The observed quantitative predominance of small custom mills (Table 7) is not simply a product of the sampling frame adopted. It is a real phenomenon that could possibly be explained by their flexibility, characterized by substantial ease of entry. One notable flexibility is the simple mechanical and operational technology that does not require skilled labour during operation. Ease of entry into custom milling is also facilitated by its "informal" character and the absence of strong institutional barriers to entry. Thus, although a custom mill requires a licence to operate, it is not, unlike the merchant mill, subjected to intense government interference. In most

Table 7. Sample milling firms by location and ownership pattern.

Mill type and production (tonnes/day)	Location		Ownership				
	Rural	Urban	Individual	Partnership	Village	Public	Total
Maize hammer							
4–8	21	15	31	1	4	0	36
8.5–22.5	0	5	3	2	0	0	5
24	0	2	0	0	0	2	2
Maize roller							
24	0	2	0	0	0	2	2
50	0	2	0	0	0	2	2
120	0	2	0	0	0	2	2
Small rice huller							
4–8	5	6	9	0	2	0	11
Rice rubber roller							
24	0	2	0	0	0	2	2
60	0	1	0	0	0	1	1
120	0	2	0	0	0	2	2

Source: Survey data.

of the urban areas, for example, the milling fee was not officially monitored during the survey.

However, in a few urban areas (such as Mwanza and Arusha) and in some rural areas where the local governments had set up an official milling fee, this was normally considered low by millers, who subsequently charged their own milling rates. Thus, even in areas where official milling fees existed, they were not being closely monitored by government officials. In some rural areas with excess demand, custom millers could charge a monopoly milling fee. Two other important factors that facilitate ease of entry into custom milling include the modest demand they place on skilled labour and low initial investment costs.

Employment structure

The employment structure of the sample firms is summarized by technology type in Table 8. Operatives include all workers engaged directly in the production process and skilled labour refers to workers who had attended any technical or vocational school. Each technology category requires different employment categories (Table 8). These differences appear to be related to both the type and scale of the technology in use. Thus, for example, family labour is confined to small-scale custom mills. Skilled labour, on the other hand, is only found in merchant mills. In all technology categories, however, the absolute numbers of workers rise with scale.

Across scale, the range is very wide. With a grain supply of about 4 tonnes/day to be weighed and fed to the hopper of the mill, the smallest custom mill requires not more than three full-time employees. On the other hand, a 120-tonne/day maize roller mill employs 20 times more workers than the smallest maize hammer mill.

Table 8. Employment by technology category.

Type of mill and production (tonnes/day)	Number of establishments	Number of workers							
		Operatives	Nonoperatives	Total	Average	Skilled	Unskilled	Family	Hired
Maize hammer									
4–8	36	86	26	112	3	0	112	26	86
85–22.5	5	23	8	31	6	0	31	7	24
24	2	22	5	27	14	3	24	0	27
Maize roller									
24	2	32	8	40	20	6	34	0	40
50	2	63	15	78	39	21	57	0	78
120	2	102	19	121	61	29	92	0	121
Small rice huller									
4–8	11	18	4	22	2	0	22	4	18
Rice rubber roller									
24	2	27	6	33	17	5	28	0	33
60	1	30	6	37	37	10	27	0	37
120	2	85	17	102	51	25	77	0	102

Source: Survey data.

Initial investment costs

Capital costs of mills vary enormously. Estimates of the initial capital costs of the various types of mills are presented in Table 9. These data, however, should be interpreted with caution. First, the figures on fixed capital do not refer to actual initial investment outlays but to estimates of their 1983 replacement cost. Second, it should be remembered that these data represent average (weighted) values pertaining to each technology size category. The actual values varied within one technology-size category as shown by corresponding range and standard deviation measures. This should be expected given differences in makes, location, size, power, and the degree of accuracy of information from operators. These figures, however, compare well with current (market) costs as given by major equipment suppliers and mill distributors in Tanzania such as the Cooperative and Rural Development Bank (CRDB) and Small Industries Development Organization (SIDO). Thus, the problem of variance notwithstanding, they constitute reasonable estimates on which the subsequent analysis can be based.

Low investment costs in the case of small custom mills can be attributed to at least three factors. The cost of land, particularly in rural areas, is low and, even in some urban cases, operators use their own residential plots to build mill sheds. In fact, in three cases, urban operators used extensions of their residential buildings to house the mill. Building costs are also reduced significantly by use of family labour and by the simple structure that the custom mill needs. Within custom milling itself, building costs differed substantially between rural and urban mills. Building costs in rural areas were, on average, one-third less than those in urban areas. These differences were probably because of the extensive use of family labour in rural areas and the more modest buildings commonly found there.

Merchant mills, on the other hand, face relatively higher initial investment costs. Their market orientation compels them to be sited in strategic urban places where the costs of land and rent are high. The sophisticated multistage structure of the mill requires special building designs such as several stories to allow gravity lines to transfer the product from one stage to another. Bulk storage for both raw material and output inventories requires more storage space, involving extra building costs. It is not surprising, therefore, that building costs for one maize roller could be sufficient to cover building expenses for 55 small hammer mills.

The range of equipment prices was also very wide across scale. The largest maize roller costs nearly 106 times as much as the smallest hammer mill. In nominal terms, however, imported hammer mills were, on average, cheaper than local hammer mills. Working capital, on the other hand, rose with scale but was of less significance to custom mills because they do not keep inventory stocks and do not pack the produce.

Utilization of economic resources

When formulating the basic industry strategy (BIS), the planners strongly emphasized that the "Basic industries — those that use domestic resources to produce essential commodities for consumers or domestic industries — will receive priority" (URT 1974:17). One important criterion for choosing an appropriate technology, therefore, is the extent and effectiveness to which

Table 9. Mean initial capital investment costs (thousand TZS).[a]

Mill type and production (tonnes/day)	Fixed capital					Working capital		
			Total					
	Equipment	Building	Absolute	Range	SD	Absolute	Range	SD
Maize hammer								
4–8								
Local	673	682	1 355	396	414	117	170	41
Imported	578	560	1 138	234	389	93	111	26
8.5–22.5								
Local	1 558	1 570	3 128	395	279	166	41	30
Imported	1 406	1 345	2 751	234	130	165	130	65
24								
Imported	7 200	2 950	10 150	800	566	1 576	886	626
Maize roller								
Imported								
24	15 410	10 285	25 695	4 470	3 130	1 896	476	338
50	44 176	14 690	58 866	5 332	3 770	4 355	807	570
120	61 542	30 758	92 300	5 639	3 987	11 171	789	558
Rice huller								
Imported								
4–8	415	512	927	872	293	93	120	31
Rice roller								
Imported								
24	11 100	6 424	17 525	1 352	956	2 775	300	212
60	29 500	14 600	44 100	—	—	5 142	—	—
120	51 075	28 195	79 270	8 180	5 784	12 034	2 261	1 599

Source: Survey data.
[a] Weighted averages.

technology uses locally available resources. In Tanzania, this should place heavy emphasis on:

- Using plentiful labour and other domestic resources;
- Economizing on scarce resources, particularly capital, machinery, foreign exchange, and skilled labour;
- Ensuring full-capacity utilization;
- Fostering linkage effects; and
- Minimizing operational costs.

Employment creation

When assessing the potential of technology to create future (direct) employment opportunities, the labour-intensity measure has been adopted. This is defined as the investment required to create one new, directly productive, person-hour, i.e., the capital–labour (K/L) ratio. Data on labour intensity for our sample firms is summarized in Table 10. As used, the term capital reflects the annual user-cost of capital. To obtain meaningful comparisons, both the K/L and capital–output (K/O) ratios have been adjusted to levels that would hold if all firms worked the same number of shifts.

Within each technology category, labour intensity diminishes systematically with increasing size (Table 10): generally, small-scale technologies require more labour per hour of operation than larger ones. Labour intensity varies widely across different technology categories. For instance, 500 TZS invested in a maize roller

Table 10. Capital costs per worker (TZS/person-hour).[a]

Mill type and production (tonnes/day)	Fixed capital	Total capital[b]
Maize hammer		
4–8	1.5	1.6
8.5–22.5	2.3	2.4
24	8.1	9.3
Maize roller		
24	11.0	11.8
50	13.0	13.9
120	16.4	18.4
Rice huller		
4–8	2.2	2.4
Rice roller		
24	12.4	14.3
60	10.7	11.9
120	14.5	16.7

Source: Survey data.
[a] Refers to directly productive hours.
[b] Working + fixed capital.

generate 1 person-day of employment whereas this same amount invested in a hammer mill generates 11 person-days of direct employment.

The observed greater labour intensity of small technologies, together with their large numbers, implies that they possess potential for generating more employment per unit of scarce (capital) investment than large ones. The greater labour intensity for small grain mills has been reported previously (Phillips 1976; Stewart 1977; ILO/JASPA 1981; Perkins 1983). It is also consistent with other findings on small firms in sub-Saharan Africa (Chuta and Liedholm 1979; Liedholm and Mead 1987; Kaplinsky 1987; Page and Steel 1984; Haggblade et al. 1987; Bagachwa and Stewart 1989).

It is instructive to explore further the skill character of the labour-force profile in the grain-milling industry. The skill mix of the labour force is important for policy because it indicates the nature and extent of constraints to an expansion of entrepreneurial supply. One salient characteristic of small milling firms (Table 8) is the lower demand they place on specialized operational and management skills because the custom mill requires little or no stock control, modest skill in plant operation and maintenance tasks, and rudimentary bookkeeping abilities. This aspect could be considered desirable for two reasons. One is that skilled labour is scarce in Tanzania. Second, it may facilitate formation of alternative skills through informal training such as apprenticeship and experience gained over time. In fact, 35% of the proprietors in the custom-milling subsector had previously served as apprentices in other milling firms. About 39% of workers in the custom mills indicated that they had received training as apprentices within or outside the current firm.

The level of formal training was very low and only 6% of the workers in custom mills had received formal training beyond primary education (standard seven). It was not unusual, however, to find one of the experienced workers in the custom mill carrying out some routine repairs whenever spare parts were available. There is no doubt, therefore, that the custom-milling subsector plays an important role, not only in economizing on scarce skilled labour, but also in the process of skill formation. Clearly, the relative lack of sophistication of custom-mill technology has made it possible for local users to operate and maintain it. It is also the simplicity of the hammer-mill design that has made it possible for local manufacturers to adapt it to the available levels of skill.

The relatively sophisticated machine design and operating characteristics of the merchant roller-mill technology require greater and more specialized managerial skills than those needed for custom milling. Merchant mills require skills to perform three main functions: general management and administration, supervision of plant operation and maintenance, and handling and packing of materials.

The first category of skills are needed by professional staff and the supporting secretarial and accounting clerks. This group of workers accounts for about 16% of the total mill employment and about 50% of total mill wages.

The second category of employment includes mainly skilled and semiskilled staff who are involved in plant operation and maintenance. Employment requirements are mainly of an overhead character consisting of shift millers, rollermen, electricians, and plant mechanics whose absolute numbers do not vary greatly with scale or capital intensity. This category of employment accounts for 15% of merchant mill employment and 30% of mill wages.

The third category of workers are those involved in handling and storage of grains and packing of the finished product. No special skills are needed to perform these functions and all the jobs in this category are classified as unskilled. This is the largest category of employment in terms of numbers employed, 69% of the total mill labour force. The category is, however, the lowest paid and accounts for only 20% of mill wages.

Clearly, skilled labour is an integral component of the labour-force profile of the merchant-milling subsector. An argument commonly advanced in favour of capital-intensive technology is that it substitutes for managerial skills that are also scarce in the developing countries. This contention is not supported by the evidence here. Indeed, in grain-milling, the most likely labour category to be displaced by automation is that of the materials handling and packing section, which accommodates 69% of the total labour-force in direct production. However, all workers in this section, including supervisors, were unskilled and the tasks they were performing did not require specialized skills. Therefore, introduction of an automatic packing line, for example, is likely to increase the demand for supervisory and skilled maintenance workers rather than displacing such skills.

An important related policy issue is the extent to which managerial and technical constraints impair the operations of the different firms and their capacities to search for technological information. In the case of small-scale (custom) mills, 85% of the entrepreneurs interviewed indicated that formal specialized skills were not a major constraint to their productive operations, provided spare parts and power were readily available. In fact, although all custom-mill proprietors surveyed had the basic functional literacy skills, only 10% of them had attended technical or vocational training before their milling units were established. Thus, although custom-mill owners were technically proficient in the milling process, they had no extensive training in financial management or business organization. Most probably, this explains why over 90% of these proprietors did not keep even a rudimentary set of books for business transactions: they simply lacked the knowledge and experience to do so. It also explains the failure of most custom mills to separate business receipts and expenditures from household incomes: which makes formal accounting difficult.

In the absence of detailed information, the extent of the impact stemming from the managerial and technical deficiencies can not be established. One can, however, speculate on the direction of this impact. For example, managerial and technical deficiencies undoubtedly constitute a barrier to the search for technological information among small-scale millers. About 70% of the small proprietors indicated that the only important source of technical information about milling equipment was from the more experienced small-scale millers already operating in the vicinity. The quality of such information was, of course, likely to be poor. Only a few proprietors (about 10%) whose equipment was financed by credit from financial institutions got some technical information from either SIDO or other relevant financing institutions.

From interviews, it was also apparent that about 80% of the small custom-milling proprietors did not have sufficient knowledge about technical information on the processing characteristics of raw grains or the cost of alternative makes and sizes of different milling equipments when their enterprises were established. Also, in several cases, new milling equipment was acquired without prior knowledge of marketing information such as potential market locations and size of the market, particularly demand and supply patterns.

Most custom millers, therefore, need a milling machine that they could afford and that promised to earn profits. The absence of clear grasp on the operating characteristics of alternative milling equipment may explain, in part, why building and equipment sometimes appeared to have been excessive or misdirected — for example, it was common, particularly in urban areas, to find three or more milling plants working below 50% capacity located in the same locality. When asked whether these were built because increased demand was expected, respondents indicated that demand was normally assumed to be a given and was not considered as a major factor in locating mills. However, some fancy large structures were viewed, as one operator put it, as an outward sign of the owner's success. In which case, proprietors may be assumed to pursue multiple objectives, one of which is to acquire a consumption good — that of personal esteem.

A crucial policy question to be asked here is whether formal training would enable small-scale proprietors to improve and rationalize their production processes. Although basic literacy and numeracy skills are essential to small entrepreneurs, the need for formal (college) or technical training is questionable. First, specialized formal and technical training is too expensive for the small entrepreneur to afford. Second, it may aggravate the problem of labour turnover because the trainee might join the large-scale sector after graduation. In such a situation, it might be more useful to encourage nonformal training, such as strengthening the apprenticeship system, imparting basic knowledge in record keeping, and providing incentives to the more experienced workers.

As already pointed out, relative to custom mills, merchant mills are more technical and management intensive. Even there, however, the weak indigenous technomanagerial capacity has been a major constraint in the formulation of a consistent technological policy generally and the smooth operation of the more mechanized roller mills in particular.

Effectiveness in the use of capital

Ideally, a firm's objective is not simply to maximize employment nor to generate additional output but to employ additional people so long as additional output exceeds what they would have been producing elsewhere. Under such circumstances, the efficiency of a production technique can be assessed by the extent to which it can use more of one input and less of other inputs to produce a given amount of output. In particular, if the observed labour-intensive mills also exhibit lower output–capital ratios, then they are inefficient relative to the capital-intensive mills. The mean capital coefficients for the sample firms are given in Table 10. The reciprocal of the capital–output ratio is a useful measure not only of average capital productivity but also as an indication of the capital intensity of technology.

Within each technology category, small-scale mills use more labour per unit of investment but involve less capital expenditure per unit of output than their large-scale counterparts (Tables 10 and 11). For example, to produce 1 tonne of maize flour, an 8-tonne/day hammer mill spends 5.40 TZS on capital whereas a 120-tonne/day roller consumes 80.50 TZS, or 15 times as much. Thus, small mills are, so to speak, fairly effective in the use of the scarce factor, capital — studies in Bangladesh (Scott and Carr 1985), India (Bhalla 1965), Indonesia (Timmer 1972),

Table 11. Labour productivity and capital requirements per unit of output.

Mill type and capacity (tonne/day)	Output (tonne/person-hour)	Capital (TZS/tonne) Fixed	Capital (TZS/tonne) Total
Maize hammer			
4–8	0.08	4.95	5.40
8.5–15	0.15	5.88	6.40
24	0.22	26.10	30.0
Maize roller			
24	0.15	57.40	61.40
50	0.17	71.90	76.90
120	0.19	61.90	80.50
Rice huller			
4–8	0.13	5.55	6.00
Rice roller			
24	0.14	39.50	45.40
60	0.16	48.70	54.50
120	0.18	48.90	56.20

Source: Survey data.
Note: Total capital = Fixed + working capital.

Kenya (Stewart 1977), and Sierra Leone (Spencer 1976) appear to corroborate this finding. The need to economize on capital expenditure is particularly desirable in the merchant-milling firms where the milling equipment is imported entirely, resulting in the outflow of scarce foreign exchange.[6] It is unfortunate, therefore, that the most capital- and foreign exchange-intensive large roller mills do not use capital as effectively as the small roller.

This observation may be reconciled with Kaldor's (1978) views. Kaldor observed that, particularly in developed countries (typified by the USA), lower capital–labour ratios tend to be associated with high capital–output ratios. He attributed this to the existence of economies of scale in the amount of working capital required per unit of output. He cautioned, however, that the tendency for a capital-intensive technique to be associated with low capital–output ratios may not be valid in developing countries. Kaldor lists six factors that he considered crucial in inhibiting capital-intensive techniques operating in developing countries from yielding higher output per unit of capital:

- Greater difficulties in operating sophisticated machines;
- High incidence of machine breakdowns;
- Limited skills;
- Undercapacity utilization;

[6] Typically, foreign-exchange costs for merchant mills are estimated to be about 65% of total capital investment whereas, for custom mills, they constitute about 20% for locally made mills and 40% for imported ones. In absolute terms, this translates to about 6 million TZS for a 120-tonne/day maize roller mill and about 27 000 TZS for a 6-tonne/day local hammer mill.

- Shortcomings in the quality and character of the educational system; and
- Inefficient and poor transport and communications systems.

Additionally, the observed wide variations in the capital–labour ratio demonstrate that factor combinations generally vary depending on the type of technological process used. When this is interpreted in the neoclassical context, it supports the supposition that a potential spectrum of production technologies exists in the grain-milling industry in Tanzania. The statistical reliability of this result is investigated more formally in the next chapter.

Factor productivity

Differences in equipment characteristics seems to result in different levels of performance. When compared to average capital productivity, average labour productivity, as measured by the output–labour ratio (Table 11), exhibits less variation within technology categories. The range among hammer mills is about 2.5 times whereas the corresponding figure for average capital productivity is six times. On the whole, the rise of average labour productivity with size within each technology category is conspicuous. For merchant milling, this result is not surprising because the larger merchant mills possess greater amounts of capital per worker. However, because the smallest merchant milling units possess higher output–capital ratios than the largest ones, the observed low average labour productivity levels among small mills may be a reflection, as White (1978) notes, of the efficient combination of labour with low levels of capital. Consequently, although gains of labour productivity are essential in a dynamic framework, the crucial issue is how additional output can be maximized given the scarce resource constraints.

The capital productivity measure can only make sense as an indicator of relative efficiency if labour and other inputs have a shadow price of zero. An attempt has been made, therefore, to establish the marginal productivities of the primary inputs to provide a crude measure for determining their opportunity costs. The respective partial elasticities of capital and labour have been estimated via the Cobb–Douglas (C–D) production function.[7]

For the grain-milling industry as a whole, the computed marginal productivities for both capital and labour were clearly positive and significantly different from zero at the 5% level of significance. In the custom-milling subsector, the marginal productivity of labour was estimated to be 60 kg (or, in value terms, 7.20 TZS) per person-hour worked, whereas that of capital was about 71 kg/TZS invested. In the merchant mills, the marginal product of labour was slightly higher and amounted to 86 kg/person-hour (about 10.90 TZS/hour) whereas that of capital was much lower and worked out to be 6 kg/TZS invested (Appendix III).

The positive results for marginal labour productivity are contrary to what is sometimes assumed and suggest that milling firms do not exhibit a disguised form

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[7]The marginal product for input i ($= MP_i$) is defined as $MP_i = a_i(AP_i)$ where a is the estimated elasticity coefficient for the input and AP_i is the average product or the output–input ratio for that particular input. See Chapter Six for details on the production-function analysis and Appendix VIII for numerical values.

of unemployment. These estimates do not provide any conclusive insights on the opportunity cost of the respective inputs. For this, one needs to know what the inputs would have produced elsewhere, not in the milling industry. In the absence of detailed information, however, these results should be used as a proxy for the opportunity costs of the respective inputs. Ideally, other potentially scarce resources such as skilled labour, management, and foreign exchange should be included so as to determine the total factor productivity. Furthermore, these inputs ought to be examined at their social prices.

Moreover, in view of differences in product quality and the extent of vertical integration, it may be misleading to conclude on the basis of marginal productivity that small mills are relatively more efficient than large mills. What is evident, however, is that small-scale custom mills can use scarce resources productively and, given a neutral policy environment, they could be potentially competitive with large-scale mills.

An attempt was also made to gauge some indications of allocative efficiency in the grain-milling industry by equating the value of the marginal product of labour to the wage rate. The value of the marginal product in custom mills, as indicated above, was about 7.20 TZS/person-hour worked. Given 100 as the mean number of monthly hours actually worked, the marginal product per month is about 720 TZS. This figure is 25% lower than the actual mean monthly wage rate of 960 TZS recorded in the custom-milling subsector. The marginal productivity of labour in merchant mills was computed as 1 630 TZS/month. This is about 10% less than the actual mean monthly wage rate for workers in this subsector. Both cases indicate prevalence of excessive employment in the industry as a whole, other things being equal, and, therefore, possibly some allocative inefficiency in the economy as a whole.

Capacity utilization

Although the concept of capacity utilization is elusive to define, it broadly relates to the way in which fixed capital is used jointly with other factor inputs (for a further discussion on the concept of capacity, see Klein (1960), Phillips (1963), and Cassels (1973)). The importance of capacity utilization lies not only in its relation to the choice of technique but also in broader issues of resource allocation and use. Underuse of capacity may be, in part, a result of an economic decision made at the time of investment. This planned, or ex-ante, capital idleness, as Winston (1979) calls it, is privately optimal being consistent with the firms expectations on factor prices. Ex-post capacity underuse, however, is unintended; being largely a result of adversities and unexpected events occurring after the investment decision.

Capacity utilization influences the choice of technique because ratios between one input and another and between inputs and output depend on it. Presence of excess capacity, for example, may raise the capital–labour and the capital–output ratios for firms that adjust their labour input to changes in output (Page 1979:19). This is bound to affect adversely the capacity of the firm to generate additional employment or to use gainfully the existing stock of scarce resources. Different levels of capacity use may, therefore, make factor intensities appear different at actual and potential output levels.

It is important to mention briefly the role of certain technological characteristics of the production process in constraining decisions at the investment stage on capacity utilization. For example, Betancourt and Clague (1977) point out the existence of economies of scale as generally implying a bias in favour of low capacity use. They hypothesize that, when a process is characterized by economies of scale, it may be profitable for a large plant to operate fewer hours per day. Thus, in the long run, investors might decide to overbuild capacity "because economies of scale mean that the cost of a little idleness now will be more than compensated by fuller utilization and higher profits later" (Winston 1974:1303).

However, the presence of indivisibilities may also create peculiar problems for small firms. "For example, a small plant cannot install only half of the smallest available steam boiler or blast furnace to correspond to its needs. In such a case, equipment purchases will inevitably involve built-in excess capacity" (Bautista et al. 1982:21). Other factors could operate in the opposite direction, however, thus offsetting the impact of economies of scale on capacity utilization. Frances Stewart (1977), for example, has demonstrated that investment-intensive plants (which also tend to be large) may operate at fuller capacity because they face a high ratio of unavoidable to avoidable costs.[8] They may, thus, have a greater incentive to economize on the larger capital costs through higher capacity utilization. On the other hand, small-scale firms may be forced to work below capacity because the indivisibility of entrepreneurship may imply that a supervisor for an extra shift would raise costs disproportionately (Marris 1964). Equally, for a labour-intensive firm, low-capacity utilization may reflect an attempt by management to avoid paying the more important labour costs for night and weekend shifts (Bautista et al. 1982).

Although it is important to recognize the importance of the technological constraint imposed by the nature of the production process on capacity utilization, it is also worth noting that its impact is not absolute. Ultimately, its influence depends on the interaction of other supply (inputs, energy, wages, etc.) and demand bottlenecks. Indeed, input-supply factors have been found to be the principal determinant of industrial-capacity utilization in a number of manufacturing firms in Tanzania (Wangwe 1979).

The rated, or maximum, capacity of the grain mill is normally an engineering variable and is technically determined. Most mill manufacturers define capacity output in terms of quantity of grain milled per unit of time. However, in Tanzania, as in many other developing countries, the work-day or work-week are not as standardized as in industrialized countries. For example, lack of sufficient lighting may make a night shift practically impossible for a rural custom mill. Moreover, the rated capacity of the mill is a theoretical rate rather than the maximum feasible in an actual work situation. For example, in three urban cases, custom millers had stretched the manufacturer's ratings by increasing speeds and feed rates.

Consequently, because rated capacity is not uniquely determined, we have found it more useful to define full capacity as an economic variable representing the desired level of output for a given mill. In other words, it is the rated (or maximum) annual capacity adjusted to the normal local conditions in the productive

[8] Stewart's argument is that investment-intensive techniques are characterized by a higher ratio of unavoidable to avoidable costs than are labour-intensive. Assuming that two techniques have the same unit costs at full capacity then, if capacity declines, the rise in unit costs will be greater for the labour-intensive technique (Stewart 1977:206).

environment surrounding the miller — there is an element of subjectivity in this definition because the number of hours and the intensity at which the plant is operated may vary because of differences in entrepreneurial perceptions and preferences. However, it does allow for time lost through scheduled maintenance work, the need to observe public and annual holidays, and the seasonality of agroprocessing. From data generated during the survey, it was found reasonable to assume a normal year of 300 working days (or 50 6-day weeks) for each firm. Excess capacity is then defined as the percentage by which current (annual) output is estimated to be below full capacity given the existing level of capital stock.

Mills were not used to full capacity (Table 12). Excess capacity rates were highest in the custom-milling subsector, particularly in small rice mills, averaging 76%. Despite the versatility of the custom hammer mill in processing different cereals, pulses, and root crops, the observed low levels of capacity utilization in this subsector should not be surprising. In the first case, the survey was undertaken during a period of general grain shortages nationwide. The previous 2 successive years of drought and the subsequent poor harvest would certainly have reduced the amount of grain that peasants could retain for their own consumption. Seasonal fluctuations affect the supply of grains and constitute another source of underuse of capacity. Custom-mill operators in the rural areas indicated that, normally, capacity utilization tended to rise during the first 2 months after the harvest season and declines gradually thereafter. It is not surprising then that 65% of custom millers pointed out irregularities in the supply of grains as a major source of capital idleness (Table 12).

Even allowing for such seasonal variations, however, interruptions in the supply of grains could be necessary because of pauses between the small consignments of customers. The total volume of grain to be milled is made up of a large number of small quantities. Thus, production is lost because the mill is idle after one

Table 12. Capacity underutilization rates and fuel costs.

Mill type and capacity (tonne/day)	Capacity underutilized (%)			Fuel costs (TZS/tonne)		
	Rural	Urban	Average	Rural	Urban	Average
Maize hammer						
4–8	72	66	69	60	54	57
8.5–15	65	57	61	56	52	54
24	na	45	na	na	45	na
Maize roller						
24	na	38	na	na	35	na
50	na	26	na	na	32	na
120	na	41	na	na	48	na
Rice huller						
4–8	79	72	76	63	55	59
Rice roller						
24	na	54	na	na	53	na
60	na	51	na	na	46	na
120	na	59	na	na	52	na

Source: Survey data; Appendix V.
na = not available.

customer's grain is processed and before the grain of the next customer is fed into the mill. It is also clear that most custom mills operate only during the day, not only because they are family owned and operated but also because they require customer participation. This is particularly so in rural areas where the problem is aggravated by lack of proper lighting during the night and inadequate public transport. In fact, this may also explain the observed differences between rural and urban custom mills (Table 12). Because of better public transportation and adequate lighting, custom mills in urban areas can work on an average of 10 hours/day compared to an average of 8 hours for the rural custom mills.

On the supply side, power interruptions were mentioned as another factor causing capacity utilization to be lower than desired. In all urban areas, electricity supply is still inadequate and unreliable. Constant power failures were thus reported in all urban custom mills. Small-scale millers cannot afford to have stand-by generators and merchant millers pointed out that, although desirable, it would be very expensive to maintain stand-by generators that could fully meet their plants' power requirements. Diesel shortages were critical, particularly in rural areas where the absence of electricity supply had forced mills to operate during daylight only.

Energy costs differed markedly both between electric and diesel mills and between custom and merchant mills (Table 12). Higher energy consumption expenditure per unit of output in custom mills is largely attributable to low levels of capacity utilization. As indicated earlier, custom mills operate intermittently. Moreover, because there is normally a fixed demand charge on electricity consumption, this is bound to raise the average energy consumption cost per unit of output as output declines. It is, therefore, not surprising that small rice mills, which had the highest excess capacity rates, were also the least energy efficient. The relatively higher energy costs of diesel mills, which dominated the rural areas, have obviously had an impact on the milling fee. Milling charges in rural areas were, on average, 15% higher than those in urban areas.

On the other hand, maize merchant mills being dependent on domestically marketed surplus and imported grains were able to draw on their buffer reserves to ensure reasonably high rates of capacity utilization. It should be noted, however, that the average capacity utilization for merchant mills in Table 12 masks important locational variations. Merchant mills based in Dar es Salaam had relatively higher utilization rates than mills located in other urban areas (Table 13). This is partly attributed to the fact that the Dar es Salaam-based maize mills had been renovated in 1979 and also, partly, because Dar es Salaam had less severe power interruptions when compared to other urban areas. The Iringa-based roller mill was reported to suffer from frequent breakdowns because of old age and chronic shortages of spares. In Mwanza, power interruptions and shortages of spare parts were reported to be the major constraints to full use of capacity.

It is clear, however, that maize mills were not constrained by supply of raw maize. In fact, NMC provided maize grain to some of the contracted private millers. Although maintenance problems and power interruptions affected rice merchant mills, their relatively lower levels of capacity utilization were partly attributed to excess capacity. Because over 50% of domestic purchases and almost all imports are in form of milled rice rather than paddy, NMC's installed capacity for rice milling, 142 800 tonnes/year, is considered even by NMC officials as more than necessary.

Table 13. National Milling Corporation (NMC) milling capacity and utilization rates.

	Type of mill	Capacity (tonnes) Installed	Planned	Actual	Capacity utilization (%)
Maize mills					
Dar es Salaam	1 roller	15 000	14 800	12 871	87
Pugu Road	1 roller	15 000	14 800	12 871	87
Mzizima	1 hammer	7 200	6 690	4 683	70
Mzizima	1 roller	36 000	25 000	17 200	68
Rwanda	1 hammer	7 200	6 800	3 740	55
Arusha	1 roller	36 000	33 700	16 852	50
	1 roller	7 200	7 000	4 662	66.6
Mwanza	1 roller	7 200	7 000	3 960	56.6
	1 hammer	7 200	6 800	2 720	40
Dodoma	2 hammers	9 000	8 500	4 335	51
Rice mills					
Dar es Salaam					
Chang'ombe	1 roller	18 000	17 800	8 820	49.5
Chang'ombe	1 roller	7 200	6 800	3 835	56.4
Pugu Road	1 roller	36 000	34 500	15 970	46.3
Kibiti	2 hullers	7 200	6 800	2 450	36
Mbeya	2 hullers	6 600	6 600	2 400	40
Shinyanga	1 roller	36 000	23 950	12 650	36
Morogoro	1 huller	6 600	6 000	1 740	29
Tabora	3 hullers	10 800	8 900	2 492	28
Mwanza	1 roller	7 200	7 000	2 510	35.8
	1 huller	7 200	6 500	1 170	18

Source: Survey data and NMC.

Interview responses indicated that the excess capacity of the rice mills was not planned deliberately because demand for the product was expected to increase. Rather, it appears to have resulted from poor project planning at the investment stage. On the whole, the analysis on capacity utilization has shown that input supply factors constitute the principal determinants of capacity utilization in the grain-milling industry in Tanzania. In all cases, it was quite clear that the Keynesian type of excess capacity, which results from deficiency in effective demand, did not exist.

Another important point to note is that different causes of excess capacity may give rise to different forms of excess capacity. In the case of rice merchant mills, where the main cause of underuse of capacity was shortage of paddy, it was somehow easy to plan and distribute downtime. With exception of the Chang'ombe plant in Dar es Salaam, the other three mills operated 2 shifts/day for 6 days/week but at lower hourly throughput rates. However, for the maize merchant mills based in Dar es Salaam where the main sources of idle capacity were mechanical breakdowns and power interruption, it was difficult for these plants to predict the frequency of such occurrences and consequently it was difficult to distribute downtime. Thus, all four mills operated on a three-shift basis 6 days/week — well below rated hourly throughput.

Because of poor records, it has not been possible to establish precisely the exact amount of time lost because of machine breakdown and power interruptions.

However, estimates by NMC branch officials at Mzizima and Pugu Road mills revealed that, for these two mills, 12 and 18% of the total annual person-hours might have been lost because of power interruptions and machinery breakdown. In terms of output, this meant that 2 850 tonnes of sembe and 4 595 tonnes of rice could not be produced. The Iringa maize mill was estimated to have lost about 25% of its total annual running time (about 3 750 tonnes) in 1983–84 because of machine breakdowns and power interruptions whereas the Mwanza maize mill was estimated to have lost about 28% (that is about 3 976 tonnes) because of these problems. What, overall, the evidence on capacity utilization tells us is that excess capacity does not appear to be mainly a function of the type of technology used. Rather, the evidence suggests that, irrespective of the type of technology in use, capacity utilization rates can be improved with increased supplies of fuel and raw materials and better planning of maintenance and repairs.

Generation of linkages

Under the BIS criteria for selecting industrial activities, the activity's potential capability to generate technological linkages is emphasized. This emphasis is reflected in the Third 5-Year Plan (URT 1976, vol. 1:43) where it is stated explicitly that, "the major objective of the 20-year plan is to restructure the industrial sector by increasing domestic linkages in order to achieve a greater degree of economic self-sufficiency." There are at least two basic arguments why technological linkages could be considered important in the transformation of Tanzania's industry.

First, industries with high linkage effects have the inherent flexibility to induce the expansion of other industries' output levels by providing them with working inputs and raw materials (i.e., through forward linkages) or by creating a market for the inputs of other industries (i.e., exploiting backward linkages). The latter attribute stimulates the expansion of input-providing industries. Thus, when high linkage industries also happen to be users of domestic resources, their development would constitute an important step toward elimination of technological dependence.

Second, knowledge about linkages may be useful in establishing a logical "sequential pattern of industrial growth, the purpose being to select the most efficient sequence which would accelerate the growth process through technological interrelationship" (Rweyemamu 1973:150). Elaborating on this by way of an example, Rweyemamu pointed out later (1981:15) that, before Tanzania can develop an iron and steel industry, "it will be essential to develop user industries (i.e., forward linkages) in engineering and metals transformation now, to provide a base for the efficient production of steel."

The establishment of basic industries and the subsequent development of linkage effects were envisaged, in the Tanzanian context, to be guided by a long-run industrial-transformation strategy. However, as Kim (1976) has established, in certain basic industries the long-run structural transformation goal conflicts with short-run policy goals of maximizing income, employment, and foreign exchange. In particular, Kim (1976:19) notes that:

> The push for rapid expansion of the basic and modern engineering industries, given the characteristics of industrial structure of the present Tanzanian economy, is likely to give rise to unintended effects of making the economy

more import-dependent in the short run and at the same time is likely to have little expansionary impact on output and income for the economy.

Skarstein and Wangwe (1986:190) using data from the 1976 input–output table found that typical basic industries show rather high direct- and indirect-linkage effects. Like Kim, they note, however, "that basic industries are highly import-intensive with correspondingly low income effects."

Ideally, the analysis of production linkages requires data from the relevant input–output coefficients of the various sectors of the economy. Whereas two input–output tables have been constructed for the Tanzanian economy (for 1970 and 1976), the sectoral breakdown is not sufficiently disaggregated to permit us to establish differences in linkage effects between custom- and merchant-milling subsectors. In the absence of such information, the volume and direction of direct transactions between the grain-milling industry and other sectors of the economy have been used to infer the relative importance of the sectors' production linkages.

It is worth pointing out, however, that two earlier studies, one by Kim (1976) and the other by Skarstein and Wangwe (1986), found that the food-processing sector was characterized by substantial structural linkages. Kim, for example, used the 1970 input–output table for Tanzania to analyze the multiplier effects of linkages on income, employment, and trade balance. He found that the food-processing industry ranked high in terms of both backward and forward linkage sectoral multipliers. This observation is also supported by Skarstein and Wangwe (1986). Their findings, which are derived from the analysis of the 1976 input–output table for Tanzania, clearly show high indices of both direct and indirect backward and forward linkages for the grain-mill products sector. Their computations of backward and forward linkages were based on the preliminary draft of the 1976 input–output table. For the grain-mill products, indices of indirect and direct backward and forward linkages were 1.32 and 1.01 respectively (Skarstein and Wangwe 1986:188, table 5.3).

Indications of the existence of strong linkage effects in the grain-milling industry are also borne out in this study. It was found, for example, that about 98 and 90% of the raw materials used in custom and merchant milling respectively were raw grains. This clearly suggests that the grain-milling industry has considerable direct backward linkages to the agricultural sector. Also, as shown in the section on *Custom Milling* in Chapter Four, over half of the maize custom plants surveyed operated locally manufactured mills: each of these plants spent about 23% of its total annual expenses as capital costs. Some custom rice hullers used domestic electric motors to drive their mills. It is more likely, therefore, that the expansion of the custom-milling subsector would stimulate the expansion of the existing local mill-manufacturing plants or initiate new mill-producing plants. Thus, in the long run, it may be possible to reduce the number of imported custom mills significantly.

Except for backward linkages to agriculture and the capital-goods sectors of the serving millers, linkages of custom milling to other sectors of the economy appear to be practically nonexistent. This is clearly understandable given that custom mills do not stock packing materials. Moreover, with germ and bran retained in the meal, there are virtually no significant by-products from the unsifted whole meal produced by hammer mills. Forward transactions are, therefore, almost exclusively confined to final sales of services and products. Even where a customer preferred a fine whole meal and therefore the meal had to be passed through the mill twice with a fine screen inserted in the mill for the second milling, by-products of about 2–5% consisting of the roughest shells of maize were considered by many millers, particularly in rural areas, to be too small for any economic use.

Backward linkages from merchant milling to other sectors of the economy, apart from agriculture, are limited solely to local firms producing gunny bags for packing meal: the cost of packing material is the second largest cost component in merchant milling (Appendix IV). The demand for packing materials, which are largely gunny bags, varied almost in direct proportion with the volume of throughput. NMC's demand for maize and rice gunny bags for the year 1983–84 was 1.6 million bags. If mills had been operating at full capacity, the number of bags required would have more than doubled to 3.5 million.

The sifting process of maize by maize roller mills produces a by-product, a mixture of germ and bran, that is an important input into the poultry- and animal-feed industries. Because sembe standard was being produced at an average extraction rate of 90%, the extraction rate for maize by-product (mainly maize bran) was estimated to be about 8% (i.e., at about 7.2 kg/90 kg of raw maize), implying a 2% milling loss. Although, at the time of the survey, no attempt had been made to separate germ from bran for oil extraction, NMC officials pointed out that germ by-products could, potentially, be instrumental in setting up an oil-extraction plant. This, it was further argued, could reduce the country's dependence on imported vegetable oil. Bearing in mind that the NMC is involved in other food-processing activities such as baking, fruit canning, and poultry and animal feeds, as well as grain milling, the arguments for forward-linkage effect has been advanced by NMC officials as one of the reasons favouring the expansion of the merchant roller-mill capacity.

The linkage effect argument, however, should be seen in the light of other counteracting factors. The expansion of roller-mill capacity, for example, may result in closure of small-scale mills. The direct- and indirect-employment and income-distribution effects resulting from such closures should not be overlooked. Moreover, it is more likely that, because some of the small maize mills use locally made hammer mills, such closures could have adverse effects not only on milling firms but also on domestic suppliers of milling equipment. In any case, the economic viability must be assessed for establishing an infant maize-oil extraction plant where domestic alternative sources of vegetable oil already exist and, in fact, are currently operating below desired levels of capacity.

The potential advantage of forward linkages and the alleged foreign-exchange savings arising from the perceived reduction in imports of vegetable oil should, additionally, be weighed against increased foreign-exchange expenditure on imported roller mills. In this case, it is quite clear that a conflict exists between linkage-maximizing strategy and the trade balance-improving strategy. This seem to be in line with other findings where Kim (1976) and Skarstein and Wangwe (1986) have also noted the unintended negative effects of basic industries on the economy's trade balance.

Rural-consumption linkages, which result whenever widespread increases in farm incomes generate a pattern of rural expenditures that stimulate the expansion of rurally produced labour-intensive consumer goods and services, are potentially more important with the development of custom mills. This is mainly because, as already pointed out, custom mills employ production techniques that are small scale and labour intensive, use mainly domestic resources, and are efficient. They also produce products that are relatively cheap and hence compatible with the low-income earners who constitute the majority in rural Tanzania. Thus, the development of custom mills will not only be associated with adoption of appropriate technology but also with increased rural consumption linkages.

Given the imperfect nature of the data and the limitations of the sample, any conclusion on this must be extremely tentative. Nevertheless, it does seem possible to draw the following broad inference. The fact that the choice of industrial activities leads to a policy trade-off suggests the need for proper sequencing of industrial activities and their gradual and piecemeal implementation, particularly for an economy such as Tanzania's whose import capacity is seriously constrained. It also makes it imperative that planners should recognize the fact that it is not only the choice of activity that has to be consistent with the structural characteristics of the economy but also the choice of technology. Indeed, one of the weaknesses of the BIS, which was pointed out earlier, is that it concentrated mainly on providing guidelines for selecting industrial activities but was not explicit on the question of technology choice.

Profit and surplus generation

An important dynamic factor that might influence the decision to acquire a certain type of production technology is the potential to provide further expansion of investment opportunities. The Galenson–Leibenstein type of investment expansion has always centered on relative profits, savings, surplus generation, and reinvestment rates. Galenson and Leibenstein (1955) and Sen (1968) emphasized the need for investment criteria to maximize the flow of net investment that is created by a unit of investment today. They contended that, even if efficient, small-scale, labour-intensive processes exist, large, capital-intensive techniques should be chosen. This is because, they argued, capital-intensive processes generate the most savings and reinvestment that, in turn, induce the most growth of output and employment over time.

That this happens is mainly attributed to the higher returns (of profits) generated by capital-intensive processes and the tendency for capital owners to have higher savings and reinvestment rates than workers. If this was true, then small-scale mills would appear to provide less support for growth for the economy than merchant mills. A trade-off would then exist between a strategy that sought to maximize employment and the one that sought to maximize the rate of growth.

This conflict can be illustrated more clearly by using a simplified version of Sen's (1968) model. If two production techniques T_c and T_l are assumed and both employ the same amount of fixed capital (F_k) but with differing amounts of labour (L_1 and L_2 respectively). If it is further assumed that technique T_l employs more labour, produces higher output (OQ_2) in absolute terms, but has lower labour productivity than T_c, whose output is OQ_1. Now, if the wage rate is assumed to be fixed and if there are no savings out of wages, then an increase in employment would raise the wage bill ($w{\cdot}L$) linearly (Fig. 5). In this figure, the east axis (OL) represents the amount of labour that can be employed, the north axis (OQ)

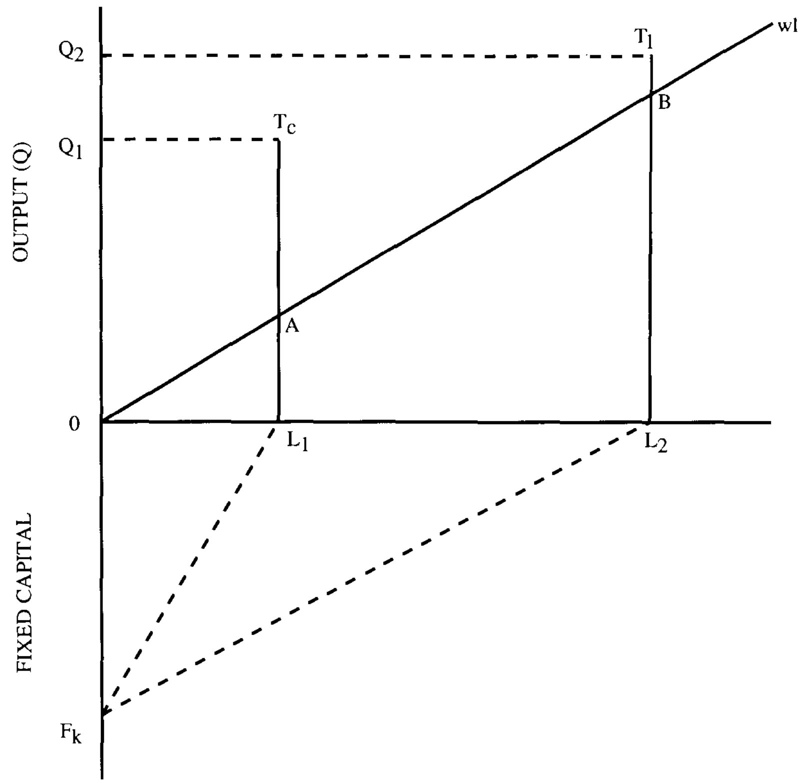

Fig. 5. Surplus–employment trade-off.

represents output (Q), and the south axis represents the fixed amount of capital (FK) that is employed by the two techniques.

It is quite clear that surplus (defined as excess of output over wage costs) is higher and employment is lower for technique T_c than technique T_l (i.e., $T_cA > T_lB$ and $L_1 < L_2$). The implied rate of reinvestment is also higher for technique T_c (i.e., $T_cA/Q_1 > T_lB/Q_2$). Thus, the decision to choose technique T_l or T_c would clearly depend on whether one wishes to maximize employment (technique T_l) or to maximize surplus (technique T_c).

Under special assumption, however, the rate-of-reinvestment criterion turns out to be the same as the classical cost-minimization criterion. This is illustrated by Sen (1957) who has restated the Galenson–Leibenstein's rate of reinvestment criterion (r) as follows:

[1] $r = (q - w{\cdot}L)/c$

where q = output (presumably net output) per machine; L = the number of workers per machine; w = real wage rate; and c = cost per machine, which turns out to be similar to the capitalist's rate-of-profit criterion. Sen (1957:564–565) explains this coincidence: "If the whole of the profit is reinvested and the whole of wages consumed, the rate of profit and the rate of reinvestment must come to the same thing." The relationship between the reinvestment criterion and the Harrod–Domar growth-rate formula is also brought out clearly by Sen in the following manner:

[2] $r = (q - w{\cdot}L)/c = [q/c][1-(w{\cdot}L/q)] = s/a$

where a = capital coefficient (= c/q); and s = savings ratio (= $(q - w{\cdot}L)/q$) which suggests that the maximization of the rate of reinvestment is the same as maximizing the rate of growth.

From the expression in function [1], it is clear that the surplus (or return to capital) directly generated by a technique is equal to $(q - w{\cdot}L)$. In other words, if it is assumed that all profits are saved and all wages consumed, then surplus generated by a technique should be equal to the value added less the wage bill (Sen 1968). Stewart (1977) has argued that if surplus is defined this way then it is likely to be importantly influenced by both the degree of factor intensity and the prevailing mode of production. In particular, the use of the surplus-generation criterion would tend to be biased against labour-intensive techniques, which have larger wage bills. Moreover, whereas in a planned economy it can be rightly assumed that all profits are saved, it is not safe to assume the same for a private economy where part of the profits may be consumed. In the latter situation, Stewart (1977:195) defines the relevant surplus (S) as:

[3] $S = sp(V - w{\cdot}L) + t{\cdot}w{\cdot}L$

where sp = the propensity to save out of profits, V = value added, w = wage rate, L = number of employed workers, and t = the propensity to be taxed out of wages.

This suggests that at least three empirical components that bear on the issue of surplus generation ought to be examined. The first relates to differences in savings propensities from profits and employment income among firms. The second concerns the relative rate of profit per unit of capital generated by different milling technologies. However, if surplus is to be relevant to growth of output and employment, then it ought to be reinvested in the economy. Consequently, the last aspect relates to the differences in reinvestment propensities of milling firms. Unfortunately, we do not have data on savings propensities from employment and profit sources. Thus, the following discussion is confined to the returns to capital or profit rates and the relative reinvestment rates.

To evaluate the relative profitability of alternative technologies, the return to capital or surplus was compared to the cost of capital. The return to capital, as defined here, is the difference between value added (i.e., gross output less the cost of material inputs)[9] and the wage bill. The cost of capital depends on the underlying investment cost, the durability of capital equipment, and interest rate. We may thus define the annual cost of capital as the investment cost times the capital recovery factor.[10] More formally,

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[9] The value added for custom mills is defined as the difference between the turnover (consisting solely of the milling fee) and the costs of repairs, fuel, and cost of operating capital for intermediate inputs. For merchant mills, this consists of the difference between turnover (sales for both main products and by-products) and costs of grain, packing materials, repairs, and costs of operating capital.

[10] As defined earlier, this is the proportion of initial investment that must be recovered in each period of asset life to equate the present value of the cumulative depreciation reserve with the initial investment outlay. It is a function of the interest rate (r) and asset life (n). Thus, the annual capital recovery factor, c, equals $[r(1 + r)^n]/(1 + r)^{n-1}$.

[4] Return to capital = $V - w \cdot L$

[5] Cost of capital = $c \cdot K$

where V = annual value added, w = hourly wage rate, L = annual productive labour hours, c = capital recovery factor, K = investment cost (i.e., purchase price plus installation costs).

The ratio of the return to capital to the cost of capital is the benefit–cost ratio:

[6] Benefit–cost ratio = $(V - w \cdot L)/c \cdot K$

More conveniently, the benefit–cost ratio may be reexpressed as the difference between the ratio of value added to capital and the ratio of labour to capital multiplied by the wage:

[7] Benefit–cost ratio = $(V/c \cdot K) - (L/c \cdot K)(W)$

Expression [7] is instructive because it reveals a technology's degree of factor intensity. Ideally, acceptance of any technology project requires this ratio to be greater than one. The optimum technology project is the one having the highest benefit–cost ratio among all the alternatives.

Before proceeding with the analysis on benefits and costs associated with different techniques, I must emphasize clearly that benefit–cost comparisons between the two subsectors should be interpreted with caution in view of the marked differences in both physical, service, and market characteristics between custom and merchant mills' products. In the case of maize milling, the two subsectors do not produce the same final product and, although in rice mills both subsectors produce almost similar products, differences in production processes, enterprise organization, and markets for products are substantial enough to justify separate treatment. Consequently, the analysis reduces to benefit–cost comparisons between size categories within the same technology (product) group or subsector. More specifically, in custom milling, we evaluate the small 6-tonne/day custom mill against the relatively larger 22.5-tonne/day custom mill, both producing whole-meal flour in the case of maize. In the merchant-milling subsector, benefit–cost comparisons, are made among the small 24-tonne/day roller, the medium 50-tonne/day roller, and the relatively large 120-tonne/day roller.

There are, however, three further issues that are worth mentioning here. One is that, because surplus is defined as the difference between value added and the wage bill, maximizing the benefit–cost ratio as defined by expression [6] is tantamount to maximizing surplus per unit of investment. The emphasis on surplus generated per unit of investment can be justified on three grounds. First, this criterion serves as an indicator of relative profitability. Second, and particularly in Tanzania, capital is a critically binding constraint. Third, as already pointed out, the criterion is of significance in terms of policy because it sheds light on the sector's growth potential and whether there might be output–employment conflicts over time.

The second issue relates to the apparent bias inherent in this investment-choice criterion. I suggested earlier that there might be a problem associated with the use of surplus-maximization criterion in the sense that it may tend to favour less labour-intensive technologies with smaller wage bills. However, this need not be the case. Where a capital-intensive process is also skill-intensive, the relatively higher wage rate for skilled labour might, in fact, result in a high wage bill thus offsetting the implied bias. There is also a second possible source of worry. The milling fee (in the case of custom mills) and the price per bag (in the case of merchant mills) include elements of profits. In such circumstances, there is a possibility, therefore, that the amount of surplus generated per technology might be influenced by conditions ruling in the two product markets. In rural areas, for example, where there is little competition among custom mills and where the milling fee is not regulated, surplus generated may reflect some elements of monopoly rent. On the other hand, for merchant mills, surplus may reflect the impact of government regulation.

The resulting estimates may thus be misleading as they may reflect elements of market imperfections in the two markets that have nothing to do with the physical characteristics of a particular technology. One attempt to reduce such biases is to treat the two subsectors separately, as suggested earlier. Although such a procedure is useful in reducing intermarket distortions, it does not correct distortions arising from within the same area of the product market. Consequently, a second attempt to correct such biases will be to adjust value added so as to correspond to its social value.

Lastly, it is important to emphasize that, in the absence of detailed information on the relative savings propensities from profits and employment incomes of different groups of millers, it is difficult to test the empirical validity of the Galenson–Leibenstein thesis — that is, the tendency for small firms to possess low growth potential because of low reinvestment rates. As pointed out earlier, surplus is relevant to output growth and employment as far as it is reinvested into the economy. Not all surplus as defined above can be expected to be directly reinvested, however. In custom mills, for example, the existence of self employment implies that part of the surplus generated is used to meet the proprietor's living expenses. Similarly, in merchant mills, part of the surplus generated is used to cover office overheads. Because merchant mills are state owned, it may reasonably be assumed that much of the surplus (net of overheads) is available for reinvestment in the economy.

Evidence gathered during the survey also appears to indicate that a significant portion of the surplus generated in the custom-milling subsector is being reinvested there. It was found, for example, that both formal and informal credit to custom millers have been very limited. Of the custom millers who indicated that they had applied for loans from public credit institutions (30 of 54), only 10 were successful. Except for these few and another five millers who obtained loans from relatives and friends, survey responses indicated that a significant proportion of initial investment costs had been financed from the proprietor's own savings.

This is consistent with evidence from my earlier study (Bagachwa 1981) where, for most small-scale industry operators, personal savings constituted more than 80% of capital funds. The problem with small entrepreneurs, however, is that their profits often become mixed with savings and expenditures from other business and household activities. It may, therefore, be difficult to isolate savings purely attributable to other sources. However, when millers who owned more than one mill were asked to state sources of funds for the expansion of capital, they indicated that over 90% of such funds came from reinvested profits. Although more detailed studies and careful surveys are needed on this subject, it would not be unreasonable to assume that a significant portion of surplus generated by small millers is being reinvested in the economy.

Analysis of benefit–cost ratios

The estimated private and social benefit–cost ratios for each of the selected milling technology variants are summarized in Table 14. Two discount rates (10 and 15%), two capacity output levels, and two sets of prices have been assumed. The estimated private benefit–cost ratios are based on 1983 Tanzanian costs and prices. Because estimated private costs and benefits may diverge significantly from those that may accrue for the whole Tanzanian society, I have attempted to estimate social benefits and costs using corrected prices (see Appendix II for details).

In custom milling of maize, the relatively larger 22.5-tonne/day hammer mill generates the highest surplus per unit of investment in both private and social terms (Table 14). This would be true even if the current problem of excess capacity were to be overcome. The relatively higher returns generated by the larger hammer mill are associated more with economy in the use of labour and capital costs (per unit of output), which are about 1.8 times lower in the larger hammer mill than those in the smaller 6-tonne/day hammer mill. The superiority of the 22.5-tonne/day hammer mill is also shown by the amount of value added that is generated per unit of capital expenditure — 1.58 times higher than the 6-tonne/day hammer mill. Thus, within the custom-milling subsector, there seems to exist a potential conflict between

Table 14. Benefit–cost ratios.

Mill type and capacity (tonnes/day)	Market prices					Shadow prices
	r = 10%		r = 15%			
	Current capacity	Full capacity	Current capacity	50% capacity	Full capacity	Full capacity
Hammer mill (6)						
Electric imported	2.04	7.46	1.55	1.55	5.65	3.22
Electric local	2.25	6.93	1.70	1.55	1.14	3.27
Diesel imported	1.78	5.88	1.35	1.14	4.43	2.58
Diesel local	1.36	5.66	1.03	1.51	4.29	2.67
Hammer mill (22.5)						
Electric imported	6.26	12.79	3.93	2.22	9.63	5.59
Electric local	6.05	12.42	3.79	2.00	9.29	7.18
Maize rollers (all electric and imported)						
24	1.49	2.51	1.01	0.46	1.82	0.79
50	1.61	2.06	1.17	0.36	1.49	0.78
120	1.12	2.04	0.81	0.31	1.48	0.77
Rice huller (6)						
Electric imported	3.45	14.54	2.60	4.10	10.95	7.94
Diesel imported	2.97	12.98	2.24	3.79	9.78	7.07
Rice rubber rollers (all electric and imported)						
24	1.31	3.88	0.95	0.89	3.46	2.52
60	1.55	3.38	1.14	0.76	2.45	1.69
120	1.16	3.03	0.85	0.70		

Sources: Appendices V and VI.

employment generation and output growth because the smallest and most labour-intensive hammer mill is associated with lesser surplus per unit of capital invested.

Electrically powered custom mills are relatively more profitable than diesel-powered mills (Table 14). This is attributed mainly to lower average annual fuel and capital costs. Fuel and capital costs produced by an electric-powered custom mill average about 30.90 and 20.25 TZS/tonne respectively. For a diesel-powered custom mill, however, fuel costs amount to 38.25 TZS/tonne whereas capital costs average 24.40 TZS/tonne (Appendix IV). Generally speaking, electric-powered mills are cheaper to purchase, install, and operate than diesel-powered mills. This is also reflected by the predominance of electric-powered mills in urban areas. In other words, in urban areas — where there is a choice between electric and diesel power to drive a custom mill — electric power is preferred.

When compared to local mills, imported custom mills appear to be marginally more profitable at the ruling market prices. This is because imported milling equipment is, on average, cheaper than that produced locally. This observation needs further qualification, however. Certainly, the scarcity of foreign exchange and the possible overvaluation of the Tanzanian shilling imply that 1 TZS of imported capital costs more than 1 TZS of domestic capital equipment.

When this is considered, the net social benefits generated by the locally made mill is enhanced, tilting the balance in its favour (Table 14, last column). Thus, at appropriate shadow prices, and assuming full-capacity utilization, the locally made custom-mill technology produces a unit of output using 2% less capital costs than an imported mill of the same size. Clearly, the social optimality and therefore the preferred choice for the domestic custom mill is obvious. On the whole, this analysis demonstrates that both the small and large hammer mills are economically feasible at both market and shadow prices when operated at full capacity. At the current capacity levels, however, they can only be economically feasible at market prices.

In the merchant-milling subsector, the smaller 24-tonne/day rollers, which maximize employment, were also found to be associated with higher surplus per unit of investment when valued at the appropriate shadow prices. This result reflects the fact that the smaller rollers are relatively cheaper machines and generate higher value added per unit of capital invested. Capital investment costs per unit of output were cheaper for the 24-tonne/day rollers than those for the 120-tonne/day rollers by 1.04 times for maize and 1.23 times for rice. Value added generated by the 24-tonne/day rollers per unit of capital invested was 1.15 times higher for maize mills and 1.44 times higher for rice mills than that generated by the 120-tonne/day rollers. Thus, if full capacity operation is assumed, and given the existing market cost–price structure, benefit–cost ratios for a 24-tonne/day roller are 23 and 58% higher for maize and rice mills than for a 120-tonne/day roller.

In terms of social benefit–costs, the differences widen slightly to 26 and 68% in favour of the 24-tonne/day roller. Thus, in relation to the smaller 24-tonne/day roller mill, the larger 120-tonne/day mill turns out to be technically inferior. This result clearly demonstrates that the criterion of surplus maximization does not, as is sometimes assumed, point to the most capital-intensive technology.

Sensitivity analysis

The sensitivity of the choice of technique to changes in the discount rate is also shown by Table 14. In this case, the choice of technology is apparently invariant to changes in the discount rate. A change in discount rate from 10% to 15% results in a general decrease in profitability leaving the ranking of alternative milling projects unchanged.

As expected, however, the impact of excess capacity is to reduce the overall profitability of projects. At 50% capacity, all merchant mills become uneconomic to operate. However, the rate of decline in profitability is not uniform across technologies. It is much faster for the most capital-intensive merchant mills. This may be explained by the fact that, whereas investment costs per unit of output vary in inverse proportion with decreases in capacity utilization, fuel and labour costs vary less than proportionately because of standing charges and overhead labour. In fact, given institutional rigidities in the form of labour–union regulations, it is not safe to assume that part of the permanent labour force will be temporarily laid off during periods of low capacity utilization. Thus, with the exception of casual labour, a significant portion of the labour costs in merchant mills are assumed to be overhead in character and, therefore, invariant with capacity-utilization levels. In such circumstances, labour costs per unit of output would tend to rise as capacity utilization falls.

A crucial point to be noted here is that one does not expect that mills will switch from using one type of milling technology to another in response to variations in capacity utilization. Rather, the rationale for analyzing capacity utilization in relation to choice of technology lies in the miller's expectation at the investment stage. In particular, if a miller expects capacity utilization to vary over time, he may be encouraged to choose a technology that, although not optimal at full-capacity utilization, will be cheaper to operate when capacity is underused. It is more likely, therefore, that when capacity utilization is expected to vary, the more labour-intensive technology will be preferred. This will tend to be the case as far as unskilled labour is assumed to be an essentially variable factor and capital a fixed factor because process labour may be laid off as capacity utilization declines leaving fixed assets underused.

Changes in imported machinery prices (following, for example, devaluation of the Tanzanian shilling) reduce the benefit–cost ratios of merchant mills but leave the ranking of merchant roller mills unaltered. They do, however, affect the choice of technique in the custom-milling subsector. For example, assuming full capacity, an increase of 30% in the price of imported hammer mills reduces the benefit–cost ratios (at market prices) of the 6-tonne/day hammer mill from 5.65 to 5.22 and that of the 22.5-tonne/day mill from 9.63 to 9.29, thus tilting the balance in favour of locally produced hammer mills.

Some factors influencing the selection mechanism

These analyses on input coefficients and benefit–cost ratios clearly demonstrate the economic viability of the custom-milling subsector in terms of employment generation, effective use of capital, and generation of surplus. This subsector also provides vital milling services to most of the population in both rural and urban areas. The subsector's flexibility in terms of relatively low initial investment costs and operational manageability provide additional incentive for the development of the Tanzanian small-scale entrepreneur. The implied income effects, therefore, could be great, an aspect that is crucial in ensuring rural–urban balance.

Because both the custom-mill technology and the small 24-tonne/day roller have the largest potential to generate employment opportunities and profits in both private and social terms, the decision taken by the NMC (in 1970, 1979, and 1983) to expand its milling capacity on the basis of large 120-tonne/day roller mills needs explaining. Even as early as 1970, NMC envisaged in its long-range planning that it would be "necessary to increase roller mill capacity and gradually phase out existing hammer mills" (NMC 1971:3). This was to be done because of the expanding demand for superior sembe and the alleged unreliability of the hammer mills.

Ten years later, the World Bank (1980:14) still maintained this stand: "In fact, however, NMC's hammer mills are not reliable, breakdowns are frequent, the extraction rate cannot be controlled and the quality is therefore not high." Thus, it seemed clear from the outset that the subsequent decision to expand NMC's milling capacity was supposed to have been guided by, first, the desire to phase out existing hammer mills and, second, to expand the merchant milling capacity on the basis of large 120-tonne/day roller mills.

Apart from the need to satisfy consumer preferences, the unreliability of custom-mill technology, and the forward-linkage effect mentioned earlier, interview responses from the technical staff at the NMC headquarters indicated that engineering efficiency could have been an important factor favouring the expansion of the capacity of 120-tonne/day roller mills. Most head millers interviewed spoke highly of the larger roller's in-built engineering efficiency as reflected by its higher rated physical output per unit of time. In relation to rice rubber rollers in particular, it was alleged that the larger rollers had a lower percentage of broken grains and superior drying techniques.

A strong belief was also expressed by millers about the larger roller's ability to generate important economies of scale arising from the indivisibility of machinery and buildings. Another factor that was raised was that the small rollers were characteristic of mills of older vintage, which are almost obsolete by developed country standards.

All these factors are summarized in a recent feasibility study undertaken for NMC justifying the need to establish a modern roller flour mill at Korogwe in Tanga region. The report (TISCO 1981:1.8–2.8) asserts that:

> Roller maize milling process has got the following main advantages over disk and hammer mills:
>
> i. Large roller flour mills give better quality products because sorting and cleaning of maize is done in different stages to make sure that maize that goes for milling is free from any foreign matter;
>
> ii. It is possible to change the product mix depending upon the change in demand for semolina, germ, animal meal, and bran etc.;
>
> iii. Roller milling is overall more efficient and consumes less energy;
>
> iv. There is less wastage;
>
> v. The final products are more consistent and uniform in grade and quality;

vi. The overall milling cost is less due to saving in handling charges resulting from automation of the mill;

vii. The resultant product is more wholesome from the point of view of nutrition because it is possible to perform the milling operation under highly controlled conditions of temperature and moisture in the maize. However, storage of maize prior to milling is done in such a way as to avoid the deterioration of maize from the attack of insects etc.; and

viii. Roller flour mill with complete plan sifting equipment is the only way of getting maize flour, germs, animal feed and bran.

It is instructive to explore briefly the plausibility of these assertions. It is true that, in the early 1970s, the demand for sembe superior was increasing. This demand, however, was confined to urban areas, and, as indicated in Chapter Four, the increase in demand was not based on the nutritional qualities of sembe superior but on its taste and colour. Because the price of sembe superior was, on average, almost twice the price of sembe standard and about 2.9 times that of the whole-meal flour, sembe superior was consumed mainly by the high-income groups in urban areas. In the late 1970s, however, when maize became scarce and the government imposed a ban on the production of sembe superior, consumers readily switched to buying whole-meal flour. There were no riots or any marked form of consumer resistance. It appears that, when compared to Kenya (Stewart 1977), the consumer preference for the finely sifted flour is less intense in Tanzania.[11] Moreover, given that the production of wage goods for mass consumption is one of the aspects emphasized by BIS, one should expect that the question of consumer sovereignty should assume a low profile. In other words, because of the nutritional superiority of the whole meal and because it caters mainly for the low-income group who constitute the majority, the decision to phase out the hammer-mill technology appears to have been perverse.

This decision was particularly perverse when the alleged inefficiencies of the hammer mill have not been empirically proven. To my knowledge, neither NMC nor its consultants and aid donors have undertaken detailed studies to appraise the relative demerits of the hammer mill versus the roller mill. Such an appraisal would also have to be based on shadow rather than market prices to demonstrate Tanzania's relative efficiency in the production of the two products. It is also quite clear from this study that even the expected efficiencies of the large rollers have not been realized. It seems clear then that justification for the expansion of the roller-mill capacity has simply been based on the rated engineering performance of the roller mill and not on its actual historical performance in Tanzanian conditions. However, as stressed earlier, the rated capacity it not uniquely determined: it depends on the nature of environment surrounding the actual work situation. In the Tanzanian context, the working environment has not been conducive to the operations of the roller mill.

One may then ask why, if the engineering efficiency objective has not been realized, do NMC officials continue to emphasize the expansion of the roller-mill capacity. Part of the answer may lie in the fact that engineering efficiency may be

[11]It must also be mentioned that, whereas in Kenya Stewart reports that consumer preferences might have been strongly influenced by advertising, in Tanzania advertising is virtually absent.

used as a cover below which vested interests could be favoured by selection of modern roller mills.

The subjectivity element in technological choice in this case is not hard to conceive. Apart from satisfying the consumer preferences of the elite there is, for example, the human desire to be identified with power — the personal esteem from being a manager of a large modern, mechanized milling unit. Large, sophisticated technology, usually located in a modern-sector enclave, appears to be an important source of such identity (Winston 1979:840). This probably explains, at least partly, why, despite the reality of skill shortages at the NMC, there is still hope of expanding the larger, more skill-intensive, mechanized, roller-mill technology. This "empire building" may also explain another apparent paradox exhibited by NMC. Although it is seriously hampered by lack of qualified specialists, particularly in engineering, transport and finance, NMC is overstaffed at the nonprofessional levels.[12]

The emphasis on the engineering efficiency objective may also partly reflect the absence of adequate skills on the part of the indigenous staff to interpret and foresee the policy implications of alternative technological choices or, if such skills exist, then they are not fully used when making investment decisions. Consequently, an attempt was made to explore the degree of participation by Tanzanian experts at NMC in the process of making investment decisions. Detailed discussions with NMC officials revealed that, in all cases involving decisions to rehabilitate or establish new additional milling capacity, it was mainly the foreign financing agency that identified, selected, and negotiated with the project engineering agencies.[13] True, there were some discussions and consultations with the officials of NMC, but these were a mere formality to ensure official endorsement for the project.

After going through various project reports and having interviewed and discussed this issue at length with the top executives of NMC, I am now convinced that no active local expertise was involved in the key technological decisions: that is, from feasibility studies through civil engineering works to the identification and bargaining process with machinery and input suppliers.

It is not difficult to understand the total lack of active indigenous participation in preparing key technological tasks and making choices at NMC. What has been, and still is, lacking is the operational command or technical knowhow among the indigenous NMC staff. This problem is partly historical and partly institutional. As already pointed out, NMC was formed out of the eight nationalized milling firms. Before nationalization, these firms were mainly owned and managed by either foreigners or local Asians. The indigenous labour force was confined to unskilled tasks.

Partly because of the government policy of Africanization and partly because of financial and psychological frustration after nationalization, most former foreign

[12]The World Bank study (1980) estimated that about 600 unskilled workers were overemployed in the company's storage departments alone. NMC admits that it is considerably overstaffed, particularly in the lower levels and laid off 1 796 workers (about 45% of the labour force) in 1984–85 as part of the cost-reduction exercise.

[13]The major funding agency behind NMC's expansion of projects was the World Bank through its affiliate — the International Development Association (IDA). Other bilateral donors included the UK and Germany but, normally, these acted on the recommendations of the World Bank.

owners left the country. Rather than work in the newly formed NMC, most Asians turned to investment opportunities elsewhere in the economy. Consequently, the Tanzanian staff that took over milling functions of the NMC were professionally ill-prepared and totally inexperienced. The country, in other words, did not have the requisite technological capabilities to run the industry.

The government's response to the staffing problem was to recruit expatriates on a short-term basis. The efficacy of this arrangement was undermined by two forces. First, the recruitment of expatriates was not accompanied by a systematic training program for the local staff to understudy the expatriates (World Bank 1980; Tibenderana 1982): not until 1984 did NMC came up with a comprehensive training program. Second, in 1975, NMC widened its scope of operation to include, besides the milling function, the purchase, procurement, transport, and storage of all general grains offered for sale by farmers and parastatals. After the cooperative societies were abolished in 1976, NMC also became responsible for direct procurement of grains from villages. NMC's expanded functions took place at a time when its organization, staff, technical background, managerial capabilities, and physical facilities were not adequate to deal efficiently with expansion of both responsibility and logistical problems (World Bank 1980:10).

Even at the time of the research in 1983, the 15-year-old corporation had five key posts still vacant. These included chief accountant, cost accountant, maintenance engineer, engineering and processing manager, and silo grain-handling specialist. The most technically qualified miller held a diploma in flour-milling technology. Of the 25 branch managers, only 5 had prior experience in grain milling. The level of formal education attained by the branch managers was also quite low. Only 11 of the 25 managers had completed Form four of secondary-school education and had done at least elementary courses in bookkeeping. Certainly, with very little commercial, managerial and technical experience, all one could expect of the local staff was approval of the choices made by foreign consultants and aid donors. Clearly, the limited supply of indigenous managerial skills has fostered managerial dependence. Moreover, as far as the decision to favour capital- and import-intensive technologies is concerned, the seed for technological dependence had been planted.

Indeed, this element of managerial dependence is clearly reflected in the World Bank report (1980) on the appraisal and rehabilitation of NMC's grain storage and milling capacity. The report identified 16 top technical and managerial positions where additional staffing would be required if NMC were to perform its day-to-day operations effectively. Of the 16 positions, the 6 topmost were classified as highly specialized and required expatriates of considerable experience. The total cost for these six positions over 5 years was estimated (in 1980) to be 3.0 million USD. On the other hand, the total cost for the remaining nine positions that were to be filled by Tanzanians were to cost a total of 0.4 million USD over the 5-year project.

The report also recommended that NMC should hire services of external short-term consultants who would provide technical assistance for specific matters on a short-term basis at an average person-month cost of 7 500 USD. The report stated clearly, however, that employment in these positions should be "on terms and conditions satisfactory to IDA" (World Bank 1980:24). Undoubtedly, such an arrangement would tend to foster leakages of potential investible surplus and foreign exchange.

Another factor that may have contributed to the passivity of the NMC officials in making appropriate technological choices is foreign project finance. Indeed, in the merchant-milling subsector, the choice of financing appears to be closely connected to the sourcing of equipment. Three of the British manufactured rollers were financed by suppliers' credit from Britain while the three German-made rollers were financed by suppliers' credit from Germany. Because these were not turnkey projects, there is no reason to believe that, technically, the financial sourcing necessarily constrained equipment sourcing. However, in view of the minimal role played by Tanzanian managerial capacities in the search and selection of alternative technologies, the link between financial and equipment sourcing cannot be viewed as a mere coincidence.

The link between financial and equipment sourcing has been cited as a major determinant of technology, particularly in the Tanzanian parastatal sector, where enterprises have been forced to move down their technology preference list according to the availability of foreign financing (James 1983; Skarstein and Wangwe 1986:65). More specifically, this tendency has been observed in several industrial projects, such as the Kagera and Kilombero sugar projects (James 1983), NMC's automated bakery project (Coulson 1979), textile projects (Williams 1976; Mlawa 1983), and several projects undertaken by the Capital Development Authority (Mihyo 1981).

Overall, these findings are not unique as similar observations have been made in other studies. For example, the International Labour Office study (ILO/JASPA 1981:48) on maize milling found that:

> The small-scale roller mill is still relatively uneconomic, as is the smallest hammer mill over a 15-year project life, but the hammer mill sector as a whole is competitive with the large-scale roller mills .... Indeed, the cost minimizing alternative with a 30-year project life is the 15-tonne/day hammer mill.

Stewart, in her study of maize grinding in Kenya (1977:232), reported similar findings. She observed that, "on the assumption of equal (8-hour) operation by each technique, the hammer mills generate considerably larger surpluses than the alternatives — the local hammer mills being associated with four times the surplus of the roller mill." The efficiency and feasibility of the custom mill is thus reinforced.

Chapter Six: Economies of Scale and Process Substitution

In this chapter, the neoclassical formulation of the production function, which is developed in detail in Appendix I, is used to provide additional insights into the industry's production relationships generally. More specifically, however, the chapter presents some empirical evidence on economies of scale and factor- or process-substitution possibilities. In discussing the results, I have concentrated on the total grain-milling industry regressions and on the average results for the custom and merchant mills separately.

Economies of scale

Certain characteristics of the production process may constrain the choice of technology. One is the existence of economies of scale, which may severely limit the substitution between factors of production. Certain processes, such as those involving indivisible heavy material, may only be efficiently operated at higher scales of output. Others, particularly those producing standardized products and consequently involving well-defined processing in cutting, machining, and forming may be effectively operated by capital-intensive methods. They may thus act as barriers to the substitution of labour for capital.

Economies of scale can be grouped into three different categories. Those economies that may accrue to the economy as a whole. Such economy-wide economies, as noted by Chenery (1960), are the outcome of qualitative developments in division of labour and specialization: aspects that result from the general process of industrialization. Typically, such macroeconomies manifest themselves (Cornwall 1977:126) in the form of:

- Quality improvements in the labour force that result from general or specialized education;
- Improvements in quality of production; and
- Long and sustained production lines that involve fewer stops in production and less downtime.

A distinction is also made between external, or industry-size, economies that arise from the general development of industry and internal, or plant-size, economies that depend on organization and efficiency of management within the firm (Marshall 1922). Although the three types of economies are of interest, this study focuses on internal economies at the plant or firm level. More specifically, we are interested in analyzing the relationship between output and unit costs across different plant sizes at one particular time and not the relationship between output and unit costs in one given plant of fixed capacity over time. The latter relates to the concept of capacity utilization of the plant and is reflected in the short-run cost curve of a particular size of plant. Thus, in a Marshallian sense, we are investigating the long-run or "envelope" cost curve of an individual firm.

Economies of scale may be of various categories but their overall impact is almost axiomatic. They generally result in reduction in unit cost per unit of output as the scale of output expands. The tendency for a firm's long-run average costs to fall as output expands has been attributed to several factors.

One is that overheads resulting from basic indivisibilities and other operations (such as product design, research and development, market search costs, and costs of distributing output) can be spread over a greater volume of output resulting in lower unit costs. A second factor lies in the possibility that, with increased volume of output, labour, management, and machinery can be used more effectively and productively because of greater specialization and the use of technological aids (such as computers) that become profitable at higher volumes. This raises labour productivity with consequent reduction in unit labour costs. Third, with a large volume of output (which implies relatively greater quantities of input requirements), a firm may be able to purchase inputs at a discount. A fourth factor relates to certain technical relationships, particularly the cubic dimensions (Silberston 1972). It has been shown, for example, that for certain types of equipment (i.e., pipes, tanks, storage facilities, etc.), cost is a function of surface whereas output is a function of volume. For such equipment, the surface area tends to increase proportionately less than the volume, suggesting that cost per unit of volume increases less than proportionately with the increase in surface.

Economies of scale have been extensively studied. At the aggregate level, economies of scale have been inferred from the relationship between labour-productivity growth and the rate of growth of production in manufacturing. Cornwall (1977) surveyed these studies and noted that, generally, a positive significant relationship between the two variables has been reported. However, he raised some of the critical methodological difficulties involved that are yet to be resolved.

At the plant level, estimates of economies of scale have been derived mainly from three sources: process and plant production functions, engineering estimates, and cost-accounting data. A good deal of information about specific plant-level studies is found in the surveys by Walters (1963), Silberston (1972), and Winston (1985). Apart from the fact that firm owners may be reluctant to disclose the actual costs of their operating plants, a major problem with cost data relates to the difficulty of identifying cost changes caused by differences in scale from those caused by other variables (Hald and Whitcomb 1967:374). Griliches and Ringstad (1971) presented a good discussion on the difficulties — conceptual and empirical — involved in the use of econometric production functions, noting particularly simultaneity bias and errors in variables.

So far, evidence based on estimates from econometric production functions and engineering studies have been inconclusive. Economies of scale have been reported to be present in certain processes and missing in some others — suggesting that the issue of increasing or constant returns to scale is, at best, an empirical question.[14] However, results of studies of empirical cost functions reveal that, generally, the long-term average cost curve is weakly L-shaped and not U-shaped, suggesting that economies are likely to be more significant at lower scales than at high scales (Walters 1963; Pratten 1971): "in other words, at scales of production which would be relevant or feasible in Tanzania ..." (Skarstein and Wangwe 1986:105).

Evidence on economies of scale

The results of estimating the Cobb–Douglas (C–D) functional form in equation

[6a] $\ln Q = \ln A + \alpha \ln K + \beta \ln L + u$

by the method of ordinary least squares (OLS)[15] for the 1982 separate and joint cross-sections are presented in Table 15: these results relate to the whole grain-milling industry. Output (Q) is measured in annual tonnes, capital (K) as an annual capital service flow, and labour (L) is measured in annual productive (operative) person-hours. The notation and equation numbers adopted in this chapter are like those used in Appendix I.

Based on the 1982 and 1983 cross-sectional results, the overall fit is good with 95% of the variation in output being explained by variations in capital and labour inputs. Although the estimated coefficients for both capital and labour are statistically significant ($P = 0.05$), the computed capital coefficients are rather low, between 0.21 and 0.24.

Application of the Chow (1960) test indicates the stability of the coefficients over the 1982–83 period. The computed F-statistic is less than the critical value of F at the relevant degrees of freedom and at the 5% significance level indicating absence of any significant structural break between the 2 years. Moreover, the pooled results from 1982 and 1983 observations do not alter the separate cross-sectional results in any significant way.

Although, in all three cases, the sum of the coefficients in the unrestricted C–D function slightly exceeds unity, this departure is not statistically significant. In fact, in all three cases, the observed Titner's (1952) F-statistic is less than the theoretical $F_{(0.05)}$ value at the relevant degrees of freedom, suggesting the existence of constant returns to scale in the grain-milling industry.

However, for this interpretation to be valid, at least one qualification is necessary. These results were arrived at on the assumption that capital stock was being fully used. On the contrary, our plant-level observation (as shown in the previous chapter) indicates clearly that all sample firms do not use their planned

[14] In particular, scale effects are reported to be significant in activities where surface areas and volume relations are dominant such as in chemicals, cement, petroleum refining, and brewing or in activities such as metal finishing and timber extraction where set-up costs of production become important (White 1978). Continuous-flow processes, such as sugar refining, have also been cited as having significant scale economies (Page 1979).

[15] Originally, both the maximum likelihood and OLS methods were employed in estimating the regression equations. The results were quite remarkably similar. In what follows, results based on OLS method are reported.

Table 15. Cobb–Douglas production function for the grain-milling industry (with unadjusted capital stock).

	lnA	lnK	lnL	R^2	F-statistic	DW[a]
1982	–3.028	0.211	0.857			
	(0.285)[b]	(0.091)	(0.117)	0.95	613.1	
1983	–2.842	0.244	0.798			
	(0.288)	(0.080)	(0.104)	0.95	581.9	
Pool	–2.935	0.228	0.827			
	(0.201)	(0.059)	(0.077)	0.95	1 219.6	1.950

Source: Survey data.
[a] DW is the Durbin–Watson d-statistic.
[b] Values in parentheses are standard errors of the estimates.

Table 16. Cobb–Douglas production function results with excess capacity as an additional variable.

	lnA	$\ln K_u$	lnL	$\ln K_e$	R^2	F-statistic	DW[a]
1982	–2.199	0.303	0.830	–0.131			
	(0.094)[b]	(0.049)	(0.082)	(0.080)	0.96	759.8	
1982	–2.274	0.288	0.753	–0.040			
	(0.072)	(0.053)	(0.066)	(0.062)	0.96	676.9	
Pool	–2.252	0.294	0.779	–0.074			
	(0.056)	(0.036)	(0.050)	(0.048)	0.96	1 457.5	1.954

Source: Survey data.
[a] DW is the Durbin–Watson d-statistic.
[b] Values in parentheses are standard errors of the estimate.

capacities fully. It is instructive, therefore, to investigate whether the observed excess capital stock has a positive or negative marginal impact on output. To obtain an estimate for a firm's unutilized capital stock (K_e), we multiply the firm's installed capital stock value (K) by the excess capacity figure for the firm.[16] An estimate for used capital stock (K_u) is then found by subtracting unused capital stock from installed capital stock. Following Ndulu (1986), we reestimate equation [6a] in the following modified form:

[6a*] $\ln Q = \ln A + \alpha \ln K_u + \beta \ln L + \gamma \ln K_e + u$

Estimation of equation [6a*] by OLS method yields the results given in Table 16.

In all cases, the output elasticity coefficient for excess capacity is negative but statistically insignificant ($P < 0.05$). This suggests that the marginal productivity of excess capacity is zero. The unrestricted C–D specification was then estimated using utilized capital (K_u) instead of K given the assumption that the marginal

[16]Estimation of excess capacity is discussed in Chapter Five, *Capital Utilization*. The underlying assumption here is that the rate of overall capacity underutilization is proportional to that of underuse of capital stock.

productivity of excess capacity is zero hence allowing us to drop K_e. The estimating equation then becomes:

[6a**] $$\ln Q = \ln A + \alpha \ln K_u + \beta \ln L + u$$

The results are shown in Table 17.

In all cases, the output elasticity coefficients for both factors are statistically significant ($P = 0.05$). The coefficients do not sum to unity (but to 0.913, 0.939, and 0.946, respectively) suggesting that the industry is characterized by decreasing returns to scale. However, Titner's (1952) test shows that the sum of the unrestricted coefficients do not depart significantly from unity thus confirming the assumption of constant returns to scale.

A further inspection of the simple correlation coefficient (C_r) between capital and labour variables reveals that data from this study suffers from multicollinearity. In all three cases, the reported correlation coefficients are rather high, around 0.97. However, this is not surprising given the nature of our sample. Although, normally, multicollinearity is a serious problem in time-series studies, it may also be a problem in a cross-sectional sample of our type because of the pure size effect. The tendency is that, in a cross-section sample of this type, large firms tend to employ large quantities of both capital and labour whereas small firms usually employ smaller quantities of both factors. As a result, capital and labour inputs tend to be highly correlated.

Apart from the fact that the collinearities are inherent within the grain-milling process, I also feel that this problem of multicollinearity does not impair the accuracy of the estimated parameters very much. As already shown, the overall fit is very good ($R^2 = 0.96$) and statistically significant. Furthermore, the standard errors are reasonably small and both the capital and labour coefficients are statistically significant and fall within the widely acceptable empirical range. It is therefore assumed that the estimates thus obtained are reasonably good and no further improvement on the data has been undertaken.

The firm-size effect in the cross-section sample also prompts us to test for homoscedasticity, fearing that the large-scale merchant milling firms might show greater variability in their production behaviour (i.e., higher error terms, u) than the small-scale custom mills. However, the Spearman's rank correlation coefficients of the residuals ($r_e - Q$), obtained when each of the independent variables is regressed

Table 17. Cobb–Douglas production function results adjusted for capital utilization.

	$\ln A$	$\ln K_u$	$\ln L$	R^2	F-statistic	DW[a]
1982	–1.969	0.300	0.613			
	(0.369)[b]	(0.079)	(0.121)	0.96	738.6	
1983	–1.832	0.352	0.587			
	(0.352)	(0.075)	(0.113)	0.96	629.9	
Pool	–1.902	0.345	0.601			
	(0.251)	(0.053)	(0.081)	0.96	1462.3	1.953

Source: Survey data.
[a] DW is the Durbin–Watson d-statistic.
[b] Values in parentheses are standard errors of the estimate.

against the dependent variable, are low (0.044 and 0.015) suggesting that heteroscedasticity is not a serious problem.

What, then, could possibly explain the absence of significant economies in our sample grain-milling firms? Clearly, the unimportance of scale economies in the use of labour is explained partly by the variant nature of labour with respect to changes in scale (Table 8) but also in part by the high price of skilled labour. Quantitatively, the numbers of operatives and skilled labourers rise systematically with scale. Moreover, partly because of skill differentiation and partly because skilled labour is scarce in Tanzania, the price of skilled labour is relatively high. For example, at the time of the survey, average nominal wages for skilled operatives was four times that for unskilled. Consequently, with skilled labour being variant with scale, it is obvious that large mills will have large wage bills. In turn, this would tend to offset the effects of increasing return to skilled labour on cost per unit of output.

However, the variant nature of skilled labour with respect to scale is quite surprising. As is shown in the next section, most of the skilled labour is found in the core process of milling proper, where, ideally, the employment required tends to be of an overhead character that is quite invariant with respect to scale and machine intensity. It is apparent, then, that there is a degree of overstaffing, particularly in the 50- and 120-tonne/day roller mills, a factor that undermines further realization of scale economies arising from the use of skilled labour.

There are no significant economies of scale in the raw material inputs (Appendix IV). However, 98 and 90% of raw material used in custom and merchant mills respectively consist of raw grains and vary in direct proportion with output. Evidently, this implies constant returns to the raw material inputs. However, given that, at any level of output, the raw material input accounts for a very large proportion of total production costs (about 92% in the merchant mills), there are bound to be a limited number of scale economies in the grain-milling production process as a whole.

On the other hand, potential economies could stem from more intensive use of machinery and buildings, but have yet to be realized. For example, it is understood that, technically, there is often more spare capacity in the rolls-stand and degermer at the 50-tonne/day scale than at the 120-tonne/day scale (Uhlig and Bhat 1979:102). Furthermore, if milling plants were able to use their plant capacities fully, initial capital costs per unit of output would fall as capacity expands. For example, an average 120-tonne/day maize roller would yield five times the output of the 24-tonne/day mill (when operated at full capacity) but requires an initial investment cost of only 3.6 times that of the 24-tonne/day roller. It appears, however, that these potential indivisibilities of plant economies are not effectively used because, for each scale of plant, unit costs tend to rise with less than full capacity use.

A commonly cited explanation for the absence of significant economies in industries of developing countries is the constraint of market size. It is often argued that, in certain branches of industry, markets are often considered too small to support even the minimum economic size of plant. Because, in many industries, the minimum efficient scale tends to rise over time, this tendency acts as a barrier to the pace of industrialization. In this study, however, failure to achieve economies is not, strictly speaking, because of the small size of the market (i.e., in terms of demand for output) but rather because of the weak industrial base. Because of the underdeveloped economic structure, supply rigidities in the form of water shortages, electric-supply cuts, and constant machine breakdowns caused by lack of spares permeate the economy making it difficult for firms to realize full-capacity operation.

Furthermore, because of shortages of skills, not only are the extra administrative costs for the skill-intensive firms rather high, but also, as noted by Kaldor (1978), limited technological capabilities imply greater difficulty in operating complex machines, resulting in a high incidence of machine breakdowns. This observation tends to conform with Phillips' (1980) assertion that the scale curve in a country such as Tanzania may not be the same shape as one for a similar activity in a developed-market economy. Phillips attributes the failure of a developing country to realize economies of scale to factors such as differences in factor prices, infrastructural gaps, and various forms of surplus drains or capital flight.

The evidence gathered so far seems to indicate that economies of scale do not constitute a significant barrier to technological choices in grain milling in Tanzania. The absence of significant economies of scale seems to suggest that the normally alleged cost advantage of large-scale firms does not always hold. Moreover, because large-scale firms also happen to be capital intensive in this case, the production function results seem to confirm Pack's (1982) belief that there is no indication of a strong tendency favouring capital-intensive technologies as output levels increase. It is plausible then that, given discriminatory public policies against custom mills, their survival and competitiveness can be attributed to their higher efficiency and their superior ability in serving a particular market.

Elasticity of substitution

The C–D production function, as noted earlier, does not shed much light on the factor substitution issue because it is characterized by unitary elasticity of substitution. Thus, the Constant elasticity of substitution (CES) function has also been fitted to the basic data. Estimates of elasticity of substitution arrived at using the Arrow, Chenery, Minhas, and Solow (ACMS) equation are reported in Table 18:

[10] $\ln(Q/L) = a + \sigma \ln w$

where Q and L are as defined earlier and W is the average wage rate.

The results are somewhat reasonable and indicate that the elasticity of substitution is significantly greater than zero and, although they are numerically less than unity, they are not statistically so. The elasticity of substitution coefficient varies between 0.76 and 0.82. Although there are wide variations in the wage rate between firms, to the extent that differences in the quality of labour are not captured in our measurement of labour input, these results should be indicative rather than conclusive. The positivity of the elasticity of substitution is collaborated by estimates (Appendix VII) based on the estimation of Kmenta's linear approximation of the CES production function expressed in equation

[12] $\ln Q = \beta_0 + \beta_1 \ln K_u + \beta_2 \ln L + \beta_3 (\ln K_u - \ln L)^2 + u$

When evaluated at the mean level, the elasticity of substitution in Kmenta equation is around 0.75 with the returns to scale parameter of 0.98, not quite statistically different from unity.

It is also noted that β_3, the coefficient of $(\ln K_u - \ln L)^2$, is not significantly different from zero, suggesting that the C–D production function form should not be rejected. The statistical insignificance of capital and the squared difference of the two factors is because of high collinearity between the two variables. When put together, these results show that the elasticity of substitution between capital and labour is substantially different from zero, suggesting possible alternative technological choices in the grain-milling industry. This evidence is consistent with our previous finding that factor combinations (factor ratios) in the grain-milling industry generally appear to vary depending on the type of process used. The existence of this flexibility in the substitution of capital for labour would imply that there are ample possibilities for the output rate to expand.

Two other characteristics of the grain-milling process are worth investigating further. The first relates to the evidence of significant differences between technologies employed by custom- and merchant-milling firms — that is, the existence of multiple production functions. The second aspect centres on the specific location at which substitution in production takes place — that is, the issue of core versus peripheral substitution.

The results of the qualitative analysis in Chapter Five clearly suggest that, because of marked differences in product quality, market orientation, and enterprise organization, custom and merchant mills employ different technologies — that is, they face different production functions. It is not clear, however, whether such qualitative differences are quantitatively significant. It is instructive to investigate empirically the statistical reliability of these preliminary results.

To test for differences in the technologies employed, we first estimate the C–D production function form for custom- and merchant-milling firms, allowing the various parameters to vary between the two subsamples (Appendix VIII). Clearly, breaking the sample into two separate estimates reduces the variability of the independent variables in the custom-milling subsample and renders the coefficients of the merchant-milling regressions insignificant at the 5% level. Application of the Chow test indicates that the null hypothesis of no difference in the two function is not rejected at the 5% significant level.

This test is weakened, however, because all the coefficients in the merchant-mill

Table 18. Estimates of the elasticity of substitution.

	a	$\ln W$	R^2	F-statistic	DW[a]
1982	–1.704	0.780			
	(0.641)[b]	(0.072)	0.643	116.2	
1983	–2.096	0.818			
	(0.638)	(0.071)	0.670	131.1	
Pool	–1.687	0.765			
	(–3.637)	(0.051)	0.631	211.5	1.907

Source: Survey data.
[a] DW is the Durbin–Watson d-statistic.
[b] Values in parentheses are standard errors of the estimate.

regressions are statistically insignificant. The evidence of significant differences in technologies employed is, thus, not proved. It appears, however, that the cause for insignificant coefficients in the merchant-milling regression may lie partly in the limited degrees of freedom. In part too, however, this phenomenon may reflect qualitative differences in technological processes employed by the two subsamples.

When the flexible translog functional form is estimated to describe the production technology, the results are rather discouraging (Appendix IX). The fit is good ($R^2 = 0.961$) but all the coefficients are not statistically significant ($P > 0.05$). I suspect that the translog has been highly susceptible to multicollinearity because of the cross terms. Evidently, the results are quite uninformative about the possible curvature of the underlying isoquants. I also strongly feel that, apart from the degree of freedom problem (in the case of merchant mills) and the presence of multicollinearity, the evidence on differences in production functions could not be easily captured because the estimated production functions are not of the frontier type but ones based on actual performance, i.e., based on economic efficiency and hence assumed to be factor constrained.

Although the evidence of different production functions is not statistically proved, I am still strongly convinced that such differences exist. As already shown, marked variations between administrative, production, market, and organizational structures between custom- and merchant-milling firms are bound to lead to differences in decisions on technological choice. There are also differences in access to technological information. These aspects have been reflected in the observed wide variations in types of inputs required by each subsector (as indicated by marked variations in capital–labour ratios) and, in the case of maize, in differences in product quality characteristics. Additionally, and probably most important in emphasizing technological differences between the two subsectors, is the fact that custom milling is essentially a single-stage process whereas merchant milling is a multistage process. The milling process in the custom mill is achieved within a single core activity. However, as is shown in the following section, merchant milling comprises of a series of subprocesses with each subprocess employing almost a different technique of production.

Core and peripheral substitution

Although the magnitude of the estimated elasticity of substitution parameter indicates that substitution possibilities are feasible in the grain-milling process, it sheds no light on the specific location at which substitution takes place. The latter aspect is important, however, because potential choices in ancillary and core operations might differ significantly.

In this section, I investigate the relative flexibility in the use of labour and machinery between peripheral and core operations. The focus is mainly on maize milling in merchant mills where these processes can be easily isolated for closer examination. In maize milling, one core and two peripheral operations are identified. Peripheral operations include materials handling, storage, and packing. The core operation of milling involves degerming (separating germ and bran from grain kernel), sifting, and grinding.

The materials-handling section is concerned mainly with the movement and storage of raw maize. At least three technological variants could be employed at this stage.

First is manual feeding. This involves the delivery of grains in bags by lorries (trucks) or wagons to the warehouse before feeding the grains directly to the mill. Grains are unloaded from lorries manually and stacked in a warehouse. The mill is then fed continuously with grain collected from the storage shed by a labourer who splits open the bag over a hopper.

Second is semiautomatic feeding that involves the delivery of grain in bags by lorries or wagons to a silo. Bags are then slit open and fed into the silo.

A third alternative is automatic feeding that involves delivery of unbagged grains and feeding them automatically into the silo via a spout from the belly of the delivery vehicle and a horizontal screw-feeder into the silo.

An analysis of the labour requirements of each technique is useful in revealing the extent to which manual operations can be substituted for mechanical operations. Although the manual-feeding technology is the one found in use in our study, technical officers in firms were asked to estimate labour requirements for the other two technology variants. The information for a 120-tonne/day maize roller is summarized in Table 19.

Although operations in the three processes involve unskilled tasks, the marked differences in absolute labour demands between the three technology variants suggest that the substitution of manual for machine operations is possible. The predominance of manual feeding in the sample was explained in terms of the need to conform with the prevailing mode of delivery of raw grains. In particular, it was pointed out that the delivery of raw grains in bagged form would tend to encourage the use of a warehouse for storage and, therefore, the use of manual feeding. On the other hand, a delivery system based on unbagged grains would tend to encourage the use of a silo for storage and, therefore, the use of automatic feeding.

Substantial flexibility between the use of labour and machines is also demonstrated by the availability of alternative packing systems at the packing stage. Three major packing systems have been identified by the technical personnel in the firms visited. These are manual, semiautomatic, and automatic packing lines. Because of high, fast demand for grain meals, milling firms in Tanzania use a straightforward packing system. Milled flour is packed in bags of 100 kg, then stored in layers where they are immediately unstacked ready to be dispatched to various consuming

Table 19. Monthly manhour requirements in materials handling section.

	Manual feeding process (unskilled)		Semi-automatic feeding process (unskilled)		Automatic feeding process (unskilled)	
Job	Casual	Permanent	Casual	Permanent	Casual	Permanent
Unloading	768	—	768	—	192	—
Stacking	768	—	—	—	—	—
Destacking						
Slitting and feeding	—	1 344	—	1 344	—	—
Total	1 536	1 344	768	1 344	192	—

Source: National Milling Corporation.

centres. The primary tasks involved during the packing process consists of weighing out the meal, opening and filling of bags, and shaping and sealing filled bags. An alternative is bulk storage in a silo and, whenever required, packets are prepared by drawing meal from the silo.

The three alternative packing systems are markedly different in terms of the absolute number of workers required, the skills of the labour force, and capital demands (Table 20). The manual packing system, for example, requires primarily services of the unskilled operatives and places negligible demands on capital expenditure. The automatic packing line, on the other hand, performs the packing functions automatically. The little labour that it requires is one skilled supervisor-cum-mechanic per shift who can recognize and correct any apparent fault in the operation. Consequently, the automatic packing line is characterized by very high capital costs.

Unlike the peripheral processes, the core milling process exhibits some rigidities in the substitution of labour for capital. This is mainly explained by the nature of the processes involved. There are two main tasks involved at this core stage: degerming and milling proper. Degerming involves breaking maize grains and separating the germ from the endosperm of the grain. Milling proper involves transforming the endosperm grits (through repeated grinding and sifting) into meals (sembe) of different qualities.

Although various types and makes of degermers are available (Uhlig and Bhat (1979:31–35) discuss in detail the merits and demerits of degermers of various types and makes), employment requirements are of the overhead type and quite invariant with respect to scale and machine intensity. At most, in both the 50- and 120-tonne/day maize roller mills, two operatives — a shift miller and mechanic — are sufficient to cover the degerming and milling activities for a single shift. Their main job is to set the machine in operation, identify maintenance tasks, and correct some defects in the operation. Thus, the core process in the grain-milling industry is, to a large extent, technologically determined in the sense that the design principle of the core equipment does not permit easy factor substitution.

However, some form of choice exists in the source of supply of the core milling equipment. For example, different types and makes of degermers from various manufacturers could potentially be employed in the degerming operation. As Uhlig and Bhat (1979:31–35) point out, there are significant price and quality differences among degermers supplied by various manufacturers. It is possible, therefore, for a miller to benefit by negotiating for the best terms.

We may conclude this section by observing, with other authors (Uhlig and Bhat 1979; Pack 1982), that there are significant labour-using opportunities in the peripheral operations of grain milling. In the Tanzanian case, the potential

Table 20. Equipment cost and labour requirements in the packing section.

Packing system	Equipment cost (TZS 000)	Daily labour requirements: Skilled	Unskilled
Manual	79	—	30
Semi-automatic	10 200	3	6
Automatic	15 780	3	—

Source: National Milling Corporation.

exploitation of such opportunities could serve at least three purposes: employment generation, foreign-exchange savings, and reduction in search costs that would be necessary if a firm is to obtain information about alternative designs and price range for capital-intensive equipment.

In some other studies, however, several important economies of scale have been reported in grain milling. These have been attributed mainly to the intensive use of machinery, buildings, and labour. In their study on maize milling, Uhlig and Bhat reported significant economies arising from indivisibility of plant as shown by the equipment costs of the 50- and 120-tonne/day mills. They found that a 120-tonne/day mill using European equipment yielded an output 2.4 times that of a 50-tonne/day mill, but the cost of plant and machinery for a 120-tonne/day mill was only 1.4 times that of a 50-tonne/day mill. Economies in the use of labour were explained by the invariant nature of the more highly paid jobs with respect to scale (Uhlig and Bhat 1979:102). The ILO/JASPA (1981) study also found some economies of scale as was indicated by the decline in the average discounted costs as the scale increased, especially with the longer project life. It should be noted, however, that the two studies did not consider the extent of excess capacity in their assessment of economies of scale.

Chapter Seven: Major Policy Issues

This chapter focuses on the major policy issues emerging out of the preceding analyses and charts out alternative policy recommendations. Before considering questions of policy, however, it is instructive to summarize the major findings.

Summary of major findings

The principal arguments of this study can be summarized as follows. First, it has been found that technological choice is sensitive to product quality characteristics and institutional aspects of firm and market organization. In particular, it has been established that manual milling technologies produce meals that are meant purely for subsistence consumption and not for commercial sale. In the case of maize, manual mills produce meals with a relatively shorter shelf life than those produced by mechanical mills. Manual mills have also been found to be extremely labour intensive and are characterized by relatively lower throughputs per unit of time than mechanical mills. Also, because they are designed almost exclusively for use in the household economy, the technology involved is small scale and personal.

On the other hand, mechanical mills operate in a markedly different environment and produce output or offer services on a commercial basis. Even then, the structure of the mechanical milling industry is not homogeneous. Significant differences exist between custom and merchant mills. Custom mills are designed to serve neighbourhood markets, mainly in rural areas, but also in small towns and the poor, high-density areas in large towns. They grind grain for local customers at a fee.

Merchant mills, on the other hand, produce milled products that are distributed nationwide but cater mainly for urban workers. Furthermore, custom mills, unlike merchant mills carry neither inventory stocks of raw materials nor finished products. Custom mills, in other words, do not perform the storage and packing functions. The limited size of the market for custom mill products coupled with the relatively short shelf life of the whole meal (in case of maize) necessitates the use of mills with small capacities. Custom and merchant mills, therefore, employ different technologies to produce products that are differentiated and that cater for different segments of the market. It appears then, that the specification of the product is of greater importance in determining the range of feasible production technologies available. For example, the choice to produce sifted maize meals inadvertently implies the choice of a roller-mill technology.

From the above argument, it follows that valid comparison of operational performance and technological differentials between custom and merchant mills must be made with care. The two subsectors operate in different environments and are bound to face different technological constraints. However, the analysis of the grain-milling industry clearly shows that, within each custom and merchant category of milling firms, those firms operating at lower scales of output are much more important than has been generally recognized. Indeed, if these small mills were to operate in a neutral economic environment, they could contribute much more to employment creation and future expansion of output.

A second important finding from the study is that the institutional and macroeconomic policy environment within which milling firms operate has had an important indirect effect on the actual technological choices made. As noted earlier, foreign trade and domestic credit regimes that employ a rationing system for imports and loans coupled with overvaluation of the exchange rate tend to favour the large-scale merchant mills that can exercise substantial political and economic power and are characterized by a low risk of default.

Thirdly, it has been established that the grain-milling industry in Tanzania has built up over years a technological structure that is not homogeneous in terms of machine characteristics. Even within each of the separate custom and merchant milling subsectors one can observe marked differences in models, vintages, rated capacities, and sources of milling equipment. Such differences have given rise to wide variations in the observed factor intensities and operating performance among milling firms, suggesting some degree of flexibility in technological options.

Lastly, it appears that there are no significant economies of scale in the grain-milling industry and that the substitution of manual for mechanical operations in the grain-milling process is feasible. This process substitution is not uniform at all stages of production, but rather is concentrated in the peripheral or ancillary activities of the grain-milling process.

Policy implications

What then are the implications of these findings for policy? When attempting to answer this question, it is useful to distinguish between policies that have direct effects on technological choices made within the grain-milling industry from those that have indirect or marginal effects. I discuss, first, sector-specific policies before tackling the more general policies.

Sector-specific promotional policies

As regards to the first finding, to the extent that the choice of product mix and the choice of milling equipment appear to be inexplicably intertwined, and to the extent that custom and merchant mills cater for different segments of the markets, sectoral or product bias will have important policy implications with regards to the range of technologies available and income distribution effects.

The link between product choice, factor intensity, and income distribution strands follows. Because traditional milling methods and custom mills cater mainly for rural areas and market towns, they naturally tend to use resources that are relatively abundantly available (such as unskilled labour). Moreover, their products are directed at meeting the needs of the customers they serve. These customers happen to be primarily those with low incomes. On the other hand, the primary source of demand for sifted meals comes from high-income consumers in urban areas. To meet this type of demand, relatively highly mechanized mills have to be employed. There is thus a close association between factor intensity and product quality characteristics. In particular, low-income products (such as the whole meal) are associated with relatively labour-intensive methods of production, whereas high-income goods (such as sifted meals) tend to be associated with capital-intensive methods of production.

Stewart (1977) has examined the relationships among income distribution, product characteristics, and production technology in a historical context. The tendency, she argues, has always been that, to counteract rising wages and, at the same time, to meet the changing consumption habits of the high-income countries, the direction of technological change has been toward large-scale production of high-quality products through growing capital-intensive methods of production. Rosenberg's (1976) analysis of the British experience corroborates this tendency of fashioning technology to meet specific consumer tastes.

As a result of this development, the technological options, particularly those available for use in developing countries, have been narrowed down. That this occurs, is mainly due to three factors.

- First, it is assumed that because the new capital-intensive technologies being innovated are more efficient, they inevitably supersede the older intensive ones, which become obsolete and thus the equipment embodying them ceases to be produced.
- Second, to the extent that the direction of technological change is toward large-scale production, the range of techniques available for small scales of output becomes narrower.
- Lastly, when a technique is developed to produce a specific product, choosing to make that product dictates the choice of that particular technique.

I have already discussed this issue of technological rigidity at length (Chapter Two), pointing out that, in light of empirical evidence available, it should be interpreted more flexibly. Undoubtedly, the range of technologies available on the shelf will be considerably narrowed as a result of these tendencies. For example, when studying the Small Industries Development Organization's (SIDO) selection mechanism of suitable small-industry projects in Tanzania, Alange (1987:156) observes that,

> The starting point has, in most cases then, been neither the production technique nor the kind of capabilities needed for the future development of Tanzania but the selection of the product. This selection of a product and its qualities limits the available alternative techniques.

Clearly, this is not the same thing as saying that there is no choice at all.

Indeed the evidence in Chapter Five has demonstrated that efficient, labour-intensive methods of production exist in the grain-milling industry. That also, in the case of custom mills, milling equipment used is not homogeneous. Limited flexibility exists, as say, when choosing between diesel and electric custom mills or between domestic and imported mills.

Choices can also be made between employing manual or automated feeding and packing lines in merchant milling. The evidence then, clearly belies the notion of strict rigidity in technological choice. At the same time, it does not support wholly the neoclassical notion of infinite choices. Both the neoclassical and factor-rigidity views on technological choice can be viewed as representing theoretical extremes. What we observe in practice is something between the two views. In other words, possibilities for choosing among efficient alternative technologies exist in certain branches of industry even in a developing country like Tanzania. These possibilities are not unlimited, however. The nature of technological change, product characteristics, market conditions, entrepreneurial talents, and difficulty in obtaining proper information concerning technology alternatives tend to narrow the range of technologies available.

This suggests the need to ensure that entrepreneurs are aware of the range and operating characteristics of technologies that could potentially be employed. This range depends on the development and information about alternative technologies. One possible way of accomplishing this is through widening firms' access to technological information. This is necessary particularly for small millers among whom the flow of technological information is very limited. Here, SIDO could play a useful role by providing information and guidelines relating to existing and potential product markets, alternative sources of milling equipment, estimates of major cost elements, and ideal plant location.

Although SIDO has knowledgeable and experienced staff who could compile such information, it would be advisable to involve selected experienced entrepreneurs in the process. Their involvement at these early stages of decision-making and investment design would provide the potential for further learning opportunities. Such aspects of learning have been shown to be one step toward the building of indigenous technological capacity (Lall 1979; Stewart 1979; Bell 1984).

I should emphasize, however, that it is not merely the access to and possession of technological information that is of practical importance but rather the indigenous capacity with ability to assimilate the technology internally, to adapt it to special circumstances of the user, and to create innovation. Thus, apart from widening access to technological information, the skill levels of workers and entrepreneurs must be improved through improved formal and informal training methods. The latter may, in fact, be very useful because it does not remove the worker from the job. In fact, it is the gradual, step-by-step, on-the-job learning and adaptation of technology that tends to have pronounced cumulative effects on productivity (Sercovich 1980; Westaphal et al. 1984). All this would involve a conscious government policy toward financing research and development dissemination.

Apart from narrowing the range of technologies available for selection, the sensitivity of product choice to technological choice has an important impact on income distribution. For example, policy programs that favour the expansion of merchant mills (such as import and credit rationing, overvalued exchange rate, or deliberate government policy) will tend to raise incomes of urban industrial workers relative to those in the rural areas. On the other hand, policies favouring expansion of custom mills might raise the incomes of small-scale private operators relative to those in the merchant sector. In such circumstances, more neutral policies must be pursued that will ensure the development of both custom and merchant mills if income distribution between urban and rural areas is to be rationalized.

We have now sufficient evidence in support of a neutral policy that will ensure the development of both custom and merchant mills. For, as I have already shown, custom mills are better placed to serve the bulk of the population in rural areas and small towns. I clearly demonstrated (in Chapter Five) that the promotion of custom mills involves neither output loss nor potential sacrifices in employment opportunities. Moreover, experience has shown that given the underdeveloped infrastructure in Tanzania (particularly in the distribution, transport, and communication sectors) and the persistent mechanical and supply bottlenecks facing merchant mills, the capacity for merchant mills to satisfy both urban and rural demands will continue to be highly constrained. A more useful policy would then be to promote custom mills so as to cater mainly for the rural population and small market towns while merchants mills are left to cater primarily for urban needs.

The implications for policy of promoting custom mills alongside merchant mills are as follows. First, this calls for a more effective institutional promotional support from relevant institutions such as SIDO — both technical assistance and fixed capital finance; the Cooperative and Rural Development Bank (CRDB) — for fixed capital finance; and the National Bank of Commerce (NBC) — for working capital finance. Second, and more specifically, the National Milling Corporation's (NMC) planned expansion of its 120-tonne/day roller-mill capacity should not be allowed to take place and the ban on the production of superior sembe should not be lifted.

There are at least two good reasons in support of this policy recommendation. One is that, as already pointed out, a large proportion of the potential demand for milled products can best be met by expanding the custom-milling subsector. The second reason is that the 120-tonne/day roller-mill technology is inferior to 50-tonne/day rollers. In fact, the 120-tonne/day roller generates the least employment per unit of capital invested and the least surplus per unit of output. This suggests that, in the future, new investment in milling should be in the form of hammer mills and smaller rollers rather than large rollers. At the moment, however, given the existing high rates of excess capacity, investment in new mills should be discouraged in favour of rehabilitation of the existing mills so that they could operate at near full capacity.

The rationale for emphasizing rehabilitation rather than expansion of merchant milling should also be seen in light of other considerations, e.g., as pointed out in Chapter Four.

- First, there is overcapacity in the existing rice plants. The present inadequacy of NMC's capacity to meet urban food demand can, therefore, be significantly increased with improvement in capacity utilization.
- Furthermore, if the policy of liberalizing trade in food grains is pursued actively, as is suggested in the next section, part of the urban food demand could be met by the urban-based custom mills.
- Finally, because inappropriate consumption standards stem from unequal income distribution and distorted consumer preferences, policies designed to improve income distribution (through taxes, subsidies, and asset redistribution) and to popularize appropriate products (through advertising) are essential in ensuring appropriate choices of techniques and products.

Institutional and macroeconomic policies

The success of any program in rationalizing technological choices will depend, to some extent, on the appropriateness of the institutional and macroeconomic policy environment within which firms operate. Some of the policies that deserve attention are those related to the level of producer prices, marketing structure, foreign trade, and foreign exchange-rate regimes.

As pointed out in Chapter Five, about 98 and 90% of the raw material used in custom- and merchant-milling firms respectively, is raw grains. Clearly, this suggests that the grain-milling industry is strongly linked to the agricultural sector through backward production linkages.

I also pointed out (*Institutional Setting*, Chapter Four) that one of the major explanations for officially marketed food-grain shortfalls has been the drop in real producer prices coupled with an inflexible and inefficient crop procurement and marketing systems. The marketing arrangement has been inflexible in the sense that the marketing of major food grains has been scheduled for control by NMC and that barriers (road blocks) were imposed to prevent private interregional grain flows. The system has been inefficient in the sense that it has been characterized by high collection, administrative, and transportation costs as the volume of output handled declined over time. In turn, this triggered budgetary pressures as the government attempted to contain the situation through increased subsidies.[17]

Other aspects of NMC's inefficiencies manifested themselves in form of extreme delays in procuring scheduled crops and in paying farmers. It appears quite logical to expect that policies designed to raise producer incentives, and hence to induce increase in agricultural output of food grain, are likely to have important indirect effects on the level of performance of milling firms. This is more so given that one major cause of excess capacity, particularly in custom mills, has been identified as being shortages of raw grains. One important component of the producer incentive package is the level of producer prices. Thus, a producer-pricing policy that realistically reflects production costs and the cost of living conditions of farmers could have a significant positive effect on the supply of raw grains. It also needs to raise the incomes of farmers and, hence, rural consumption linkages.

Although such a pricing policy could make grain production more attractive to producers, price increases alone are not enough. For, as pointed out earlier, a rise in grain crop production may not necessarily be translated into a corresponding rise in officially marketed output because of alternative, informal, marketing channels. To be effective, therefore, a producer pricing policy must be supported by efficient crop marketing and distribution systems as well as by timely provision of agricultural inputs and incentive goods and by increased processing capacity.

Indeed, as Odegaard (1985) has shown, the monopoly role accorded to NMC in procuring, distributing, and milling grains far exceeds its managerial, financial, and technical capacities. NMC's role must, therefore, be tailored to its limited available resources. Consequently, it is extremely important that the government should

[17]Until 1980–81, NMC had an overdraft of 2 billion TZS with NBC. This was later converted to a loan being serviced by the Tanzania Government at 250 million TZS/year. It is believed that NMC losses were caused by high costs of transport for grain and maize flour, high administrative costs, and subsidies (World Bank 1984:106).

permit greater flexibility in marketing and distributing grain by allowing licenced private operators and other public institutions to compete with NMC in performing such functions.

Therefore, I suggest that NMC's role be limited first to grain processing mainly for urban areas. This is because supplies from private markets might not be adequate to meet urban demands. Second, to maintain adequate grain reserves for emergency situations and deficit areas, NMC should only be allowed to buy surplus produce from cooperative unions and commercial farmers and also to act as an agent for import and export of grains. This means that NMC will no longer be a monopoly buyer but just a buyer of last resort. These actions are intended to alter the composition of units in favour of small mills and decentralized cooperative unions, and to make NMC pursue profit maximization as a guiding objective.

The government has already initiated and undertaken a number of corrective policy measures in this direction. Some measures were undertaken as early as July 1984, long before the country concluded an agreement with the International Monetary Fund (IMF) in July 1986. Some of the policy measures have been incorporated in the 3-year (1986/87–1988/89) economic recovery program (ERP). These include the following.

- First, the government's removal of the consumer-food subsidy on retail price, which was undertaken partly to reduce budgetary deficit pressures and partly to strike a balance between the ex-store costs and the consumer price.
- Second, to arrest the continuing trend in declining real producer prices and also to provide incentives for an increased official supply of food crops, the government intends to continue setting producer prices at a level equivalent to between 60–70% of FOB prices or increase them by 5% in real terms, whichever is higher. The government has, in fact, already signalled its seriousness in this regard by raising producer prices for food crops by about 80% in nominal terms during the 1984–85 and 1985–86 budgets. The use of producer pricing policy as a tool for increasing farm profitability has been considered as being more distributive of equity than providing agricultural input subsidies (which have been lifted) because the latter tended to favour large-scale and well-to-do farmers.
- Third, concrete steps have also been taken to improve marketing and distribution of food grains. In 1983, the government ordered that all road blocks be removed to facilitate the flow of food grains among regions. One year later, the limit on private grain shipments across regions was raised from 30 kg to 500 kg (about five bags). Further, in March 1987, restrictions on private grain shipments were lifted to allow private dealers to transport any amount of food grains without seeking prior permission from NMC. In fact, the government has also indicated its willingness to licence private traders who would buy and sell grain on their own account.

At the institutional level, the primary responsibility for crop procurement, storage, and delivery to marketing centres has been restored to cooperatives. The government has also emphasized the need for cooperatives to pay farmers promptly and to collect their crops on time. Undoubtedly, all these reforms constitute real and significant developments toward rationalizing the food-marketing systems.

Although it is too early to speak conclusively about the impact these measures will have on the overall availability of food crops, some signs of improvement have been noticed. For example, according to a Marketing Development Bureau (MDB) report, 1984–85 was assessed as an above-average year with increases of about 8 and 20% in maize and paddy production respectively. MDB estimates also show that this trend is continuing and, in 1985–86, maize and paddy production were estimated to have risen by about 5.5 and 28% respectively over production levels recorded during the previous year (MDB 1986:9). There are also indications that the average parallel market prices for maize and rice, which peaked in 1983–84, dropped significantly during the period 1984/85–1987/88 (MDB 1986), and "although in absolute terms open market prices remained above official prices on average throughout the period, the gap was closing fast" (Ndulu et al. 1987:16). As a result of these trends, NMC's purchases of maize have increased on average of 40% per year between 1984–85 and 1986–87. It should be mentioned, however, that these positive developments have, at least in part, been made possible by the good weather experienced during the 1985–86 and 1987–88 farming years.

As regards the grain-milling industry, the liberalization of trade in the food market and the restoration of cooperatives would more probably stimulate the growth of custom mills in both urban and rural areas. Already some cooperatives (particularly in the Mwanza and Kagera regions) are negotiating to take over milling units currently owned by NMC but that were owned by the cooperatives before they were dissolved in 1976. Given the limited size of the regional markets and capital constraints, if the cooperatives assume the milling function at the regional level, it is unlikely that they will choose to invest in roller mills. With distribution of grains by private operators and the low-quality grain products produced by NMC, it is also becoming very clear that many consumers prefer to buy raw grains on their own rather than buy the NMC's processed meals. Besides, since 1986–87, private traders have been the cheapest source of maize grain (Maliyamkono and Bagachwa 1990).

Another important macroeconomic policy worth considering relates to the foreign-trade and foreign exchange-rate regimes. As already pointed out, quantitative import restrictions coupled with overvalued local currency would tend to discriminate against the development of custom mills. Furthermore, foreign-exchange undervaluation, by artificially cheapening prices for imports, would tend to encourage importing custom-milling equipment and, hence, might discourage domestic production of such equipment. However, because grain-milling equipment is part of the capital-goods sector that is normally regarded as a primary carrier of technological change and technological linkages, an incentive scheme must be devised that will encourage its domestic production.

So far, the Tanzanian Government has been providing foreign exchange to custom-mill operators through SIDO. A significant portion of foreign exchange channeled through SIDO comes from foreign donor-assistance programs, however. As I show later, however, this arrangement has favoured urban-based establishments where, in fact, over two-thirds of the investment has taken place. Furthermore, the predominance of donor assistance funds in SIDO's development budget has had an indirect negative impact on the development of indigenous entrepreneurship. In particular, the preference and insistence of donors to certain projects not only biases the location of industry in favour of urban areas (where it is easy for them to make spot checks) but also stifles indigenous entrepreneurial initiatives. This is further compounded by the fact that, in most of the SIDO–foreign donor negotiations, the local entrepreneur is not even involved in the early but crucial stages of product design and technology selection (Alange 1987:16).[18]

An alternative policy action is for the government to allocate foreign exchange directly to owners of small-scale enterprises by issuing them import licences. Even then, however, because of the limited administrative resources, small entrepreneurs might still be unable to undertake protracted bureaucratic procedures required to obtain an import licence. A likely outcome of this policy is that it may still favour urban-based enterprises that, because of their proximity, are more familiar with the bureaucratic import-licencing procedures.

In such circumstances, there seems to be some merit in the government's current trade-policy initiative that combines both market forces and administrative discipline. In one of the moves, the government has embarked on (since July 1984) a partial import-liberalization policy. Under this policy, both private and public individuals and institutions with their own generated foreign exchange have been allowed to import both essential capital and consumer goods and sell them at market clearing prices. It is estimated that imports worth more than 400 million USD were imported into the country in 1985 and 1986 separately — a value that exceeds the official export earnings in the respective year (Ndulu and Hyuha 1986).

A second policy initiative was the adjustment of the exchange rate in an attempt to correct for overvaluation. Subsequently, in July 1984, the Tanzania shilling was devalued from 12 to 17 TZS/USD. In March 1986, the shilling depreciated from 17 to 40 TZS/USD. Since then the shilling has been depreciating through a "crawling peg" and stood at 78 TZS/USD by November 1987. In July 1989, the rate was 145 TZS/USD.

Because grain-milling equipment (and accessories) are among items that individuals and institutions can import using their own foreign exchange, it is expected that the spare parts that are essential for full-capacity utilization will be more available. It has also been shown (Chapter Five) that the benefit–cost ratios were very sensitive to changes in the prices of imported milling equipment. Thus, price rationing through devaluation, by raising the cost of imported milling equipment, could make it possible for domestically produced milling equipment to be competitive even at market prices.

Such a policy package that combines selective trade liberalization and devaluation has known advantages. Although it is advisable to protect the infant domestic firms manufacturing capital equipment, particularly during the early stages of industrial development, it is important to realize that, when competition from imports is completely removed, domestic enterprises have fewer incentives to innovate or improve quality. There are cases that illustrate this point. For example, India's ban on imported new looms in mills is said to have encouraged the use of the relatively labour-intensive but less profitable power looms. Similarly, the restriction on the expansion of sugar-refining mills boosted the production of semirefined sugar, a process that was not only less profitable but also less labour intensive (Little 1987).

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[18]See, for example, a recent study by Maliyamkono and Bagachwa (1990). Besides, other physical and technical factors — such as weather or agronomic conditions, levels of agricultural husbandry, and technology — may limit grain-production capacity. Similarly, relative prices, particularly those between food and cash crops, may cause sectoral shifts.

When assessing the impact of the macroeconomic policies on the development of small industrial firms in Tanzania, Alange (1987:148) has stressed this point, noting that "... competition forces a firm to act innovatively or die." Consequently, it is important to recognize that the promotion of technological development might be facilitated by designing more flexible trade policies that allow some competition between domestic and foreign suppliers instead of imposing a complete ban on imports. In other words, infant industry protection of capital goods should be justified if the infants show signs of growing to maturity. For that matter, therefore, the protection should be for a limited time.

Standardization of milling equipment

Apart from influencing the level of performance among mills, the heterogeneous structure of the milling industry has several implications for the planners generally and for the milling industry in particular. First, the availability of different makes and models from a wide range of equipment suppliers gives rise to market variations in price, quality, performance, and durability of milling equipment. Such price and quality differences provide considerable flexibility in the choice of technology, permitting an entrepreneur to select the most competitive option. This, of course, will depend, among other things, on the extent of accessibility to technological information, uncertainties, and market risks.

Despite this increased flexibility, it is important to recognize that there are problems associated with the multiplicity of makes and models in a successive investment program. One such problem relates to the ease with which spares can be imported or manufactured locally. Because equipment parts and accessories may not be interchangeable between equipment from different suppliers, or different models from the same supplier, the problem of shortages of spare parts may be compounded. Moreover, if spares must be imported, the transaction costs for shopping among various suppliers may be exorbitant.

If, on the other hand, spare parts can be manufactured locally, the heterogeneity of imported capital equipment may act as a disincentive toward development of domestic production of spare parts. This is because production of nonstandardized products does not permit a high degree of specialization that is conducive not only to an effective learning process but also to an effective application of what is learned. That is, because the technological processes are not similar, the skill acquired in one production line cannot be easily transmitted to other, similar, lines of production. Consequently, retraining costs are bound to be high and the process of technological diffusion is bound to be slow. The complications arising from capital-good heterogeneity in the manufacture of local spare parts in Tanzania have been documented in more detail in several studies, including those on textiles (Wangwe 1979; Mlawa 1983), motor vehicle assembly, and bag manufacturing (Wangwe 1979).

It is instructive to explore possible reasons that might have resulted in a heterogeneous technological structure in the grain-milling industry. Perhaps the cause lies in the absence of an explicit technological policy generally, and for the grain-milling industry in particular. Apart from the broad guidelines outlined by the basic industry strategy (BIS), we have not been able to identify a specific plant or strategy by either the ministries of industry or agriculture relating to the choice of technology in the grain-milling industry. It seems clear that, in the absence of such an industry-specific strategy, the coordination of independent technological decisions is bound to be difficult.

In the custom-milling subsector, for example, the absence of a coordinated technological strategy has meant that differences in ownership patterns could result in different choices of milling equipment. Private custom millers have tended to shop for the cheapest model available. However, for mills owned by Ujamaa Villages — which have easy access to institutional credit and grants from donor agencies — the practice has been to acquire any mill approved on their behalf by the donor.

Typically, however, most donor agencies will supply villages with mills from their own countries. Worse still, the activities of foreign donor agencies are not normally coordinated. In the Arusha region, for example, while the Centre for Agricultural Machinery and Rural Technology (CAMARTEC) and the Christian Council of Tanzania have been trying to popularize the use of manual mills in villages, the Regional Integrated Development Project sponsored by the US Agency for International Development (USAID) has openly been critical of this; and, instead, they have been vigorously promoting the diffusion of mechanical custom mills. In such cases, it is the donor who determines the source and make of milling equipment to be used.

The Tanzanian Government needs to design a program that will facilitate a more homogeneous capital structure not only in the grain-milling industry but also in other sectors of the economy. The long-run solution to this problem lies in the development of the domestic capital-goods sector and the reduction of reliance on foreign finance for development projects. In the short run, however, an interventionist and discriminatory (e.g., multiple-tariff structure) approach to technology imports can be justified.

Employment implications

The feasibility of substitution of manual for mechanical operations in the grain-milling industry implies that factor prices play an important role in allocating resources within the industry. More specifically, it shows that changes in factor prices may have significant effects on the level of employment. For example, a policy that raises the relative cost of capital, could expand employment and distribute the benefits of industrialization widely. The implication of this for choice of technology is that output can be raised and employment expanded if millers shift to more labour-intensive technologies. Because it has been shown that labour intensity is highest among custom mills and smaller roller mills, their promotion will contribute significantly to the expansion of employment opportunities. Moreover, the choice of labour-intensive technologies will be consistent with the finding of constant returns to scale that characterizes the grain-milling industry. As discussed earlier, the absence of economies of scale dispels the belief among NMC officials that capital-intensive roller mills have a cost advantage over smaller rollers and custom-milling technology.

As for policy, these results suggest that, if appropriate technological choices are to be made, it is important that domestic prices should reflect resource scarcity and factor markets should be competitive. This reinforces support for policies that seek to check the growing capital intensity of the merchant-milling subsector (e.g., devaluation, nonpreferential access to credit, etc.). The lack of technological information and the inability to use existing technologies effectively may be the cause, partly, for the failure to shift to labour-intensive technologies and their efficient use (Moore 1983:29). Therefore, a program must be designed to emphasize training aspects along the lines suggested in the section on *Sector-Specific Promotional Policies* in this chapter.

Moreover, to the extent that peripheral operations offer substantial job opportunities, the implications for policy of the observed differences between potential choices in peripheral and core operations is worth noting. This is particularly so because most entrepreneurs tend to be preoccupied with choice considerations in the core process and pay less attention to the effects arising from potential alternative technology choices in the peripheral operations.

It is instructive to distinguish two sources of flexibility in relation to technology choice: technical choice may exist in the design principle of a particular machine or in the source of supply. In the case of the grain-milling industry, we have seen that there is practically no choice in the design principle of the core milling equipment. However, there are quality and price differences in the core milling equipment from different suppliers and, although such price and quality differences do not offer significant capital–labour substitution, they permit some flexibility in the sourcing of equipment. The peripheral milling equipment, on the other hand, exhibits choices in both the design principle and source of supply.

Thus, the nature and conditions under which milling equipment is supplied to the miller constitute an important consideration in selecting technology. Milling equipment is supplied to millers in two common ways. One is for a miller to purchase a set of a core and peripheral equipment and accessories in a complete package from a single supplier. Alternatively, individual items within the package can be obtained separately from different suppliers.

Whichever way is chosen, millers should bear in mind two points when acquiring milling equipment from different suppliers. First, the potential investor must specify to the supplier the different types of compatible equipment deemed appropriate at each stage of the production process. The tendency to specify the core milling equipment alone gives the supplier some leeway in choosing the peripheral milling equipment. Therefore, because of technological progress and profit considerations, the supplier will tend to supply the miller with the modern (usually capital-intensive) equipment. The second consideration relates to the extent and reliability of ancillary services such as assistance with the installation, after-sale service (particularly supply of spare parts), provision of credit, and training courses in milling practice.

The latter consideration can best be achieved when packaged equipment is obtained from a single supplier. What is required, if one is to obtain a competitive supplier, is for the potential investor to shop around by inviting tenders from several equipment suppliers (with details of the types of machines and ancillary services required) before the actual selection is made. Apart from avoiding the problem of heterogeneity in capital equipment, this arrangement has an added advantage of reducing costs of time and search for knowledge about technological information required to knit together different machines from different manufacturers (Uhlig and Bhat 1979).

Future research questions

Finally, it is useful to highlight some of the limitations of this study to point out some gaps where future research might be useful. These limitations stem from both the nature and size of the sample and the methodology employed in the analysis.

The first limitations are imposed by the sample. It is important to recall that the analysis uses primarily data collected from grain-milling plants in operation during 1982–83. At least two difficulties are associated with data derived from existing plants. First, these data preclude a wide range of potential technologies that are currently available on the market and that could be used in Tanzania but are not actually in use now. It is, of course, not easy to assess the impact of this omission on the results. It is more likely, however, that their inclusion would have made the results more representative.

Second, as already pointed out (Chapter Three, *Data Limitations*), the use of cross-sectional data from existing plants does not provide a sufficient range of economic circumstances on which we can rely in establishing whether the observed trend is stable or unstable. An important limitation of this study, therefore, is the treatment of technological choice as being neutral with respect to the issue of technological progress. It is not clear, for example, whether capital-intensive or labour-intensive configurations in the industry studied are more amendable to later adaptations, innovations, or growth. The study is thus limited to the ex-ante choice aspects of technology; that is, choice of technology for a new plant.

The issue of technological progress is very important, however, because, for a developing country like Tanzania, it is not enough just to focus on the efficiency of the existing industrial technologies; it is also desirable to be concerned with their potential for growth. Therefore, future research is needed to establish what happens ex-post. That is, once investment is made — do additions or adaptations to existing technology provide more or less flexibility in the substitution of factors of production?

A second set of limitations stem from the plausibility of the assumptions underlying the analytical methodology employed in this study. Some of the more specific problems associated with a particular method have been discussed in various sections (notably Chapter Two, *Theoretical Approaches to Choice of Technology*; Chapter Three, *Data Limitations* ; and Appendix I, *Analytical Model*). The analyses on input coefficients, benefit–cost ratios, and econometric evaluations assume that mills are operating on the frontier of the possibility surface. This means that, with a given set of factor inputs, they can realize the maximum and technically feasible output. Which implies that resources are used efficiently and that correct decisions can be made concerning additional investment of any form. This can, however, only be possible if managers and entrepreneurs possess a clear grasp of technoeconomic knowledge about the plant facilities and are well informed about alternative production processes.

Unfortunately, these aspects are not borne out by the evidence available. Because of the lack of appropriate technical and other information on the operating characteristics of alternative technology, choices made are likely to be faulty and inefficiencies in the use of resources are bound to exist. As a result, milling firms usually do not operate with the best-practice technology. Yet, to be more useful the analysis of choice of technology not only requires information about observations from existing plant operations but also information about best practice alternatives. Thus, the absence of information about best-practice alternatives makes it difficult for planners and potential investors to determine the level of investment needed to move a plant from the current operating isoquant to the best-practice isoquant. This is another important area where future research effort could be fruitfully expended.

Appendix I: Analytical model

In this appendix, a simple static model is developed to illustrate the channels through which the miller's choice of production technology affects the level of output and hence productivity. By translating these effects into an econometric production-function model, it is possible to investigate in a more systematic manner the extent to which each variable influences the production decisions. In this form, it is also possible to investigate whether the primary production inputs act as complements or substitutes in the production process. Additionally, this scheme permits us to demonstrate whether the underlying technology differs significantly from one category of firms to another.

We begin by postulating a world milling technology set W, which comprises of all known milling technologies in the world — here, we follow closely Stewart's (1977) line of argument. We then define a set T, comprising all milling technologies that are available and can potentially be acquired by Tanzania. However, in view of information lag between Tanzania and the rest of the world, and given that some known but obsolete technologies are no longer being produced at the world level, the economy-wide set T can only be a subset of the worldwide set W.

Analogously, the firm-level set M, which consists of all milling technologies currently in use in Tanzania, can be viewed as a subset of the potentially available economy-wide set T. More formally, this can be expressed as

[1] $M\, c T\, c W$

where c stands for subset. This implies that, given the limited indigenous technological capability — to innovate and search for technological information — among Tanzanian millers, the firm-level set M is bound to be circumscribed by both the economy- and world-wide sets of available technologies.

A typical miller in Tanzania facing a potential choice of production technology t_i, can be assumed to make alternative choices from the economy-wide technology set, T. However, because T is a subset of W, which in turn has been a product of intensive research and development efforts at the world scale from the miller's point of view, the set T can be assumed to be given. Furthermore, we assume that associated with any set of technology is a set B that consists of technical and institutional variable vectors x. The elements of each vector, which include such variables as input mix, scale of operation, nature of product, and market organization, define the technology-choice variables in the miller's decision problem. Thus, the potential choices available to the Tanzanian miller can be expressed as

[2] $t_i \,\varepsilon\, T, x \,\varepsilon\, B$

The technology relation expressed by equation [2] merely describes the technical constraints that limit the range of productive processes for an individual milling firm. However, not all technically feasible transformations are of interest to the miller. Some may be efficient (in the sense that they use less of at least one input and no more of others) and hence more desirable than others. In our simple model, each miller is assumed to face a specific production decision when acquiring new technology. In particular, he is assumed to select the best level of input utilization and scale of operation for the chosen technology. However, because, for a given level of output, the selection of the best-input combination depends upon input and output prices, this assumption implies that millers face a profit-maximization problem.

Indeed, this implicit assumption is not farfetched. Ideally, one would expect grain millers in Tanzania to be profit maximizers. For example, the statute establishing the National Milling Corporation (NMC) requires it to run as a profitable commercial entity. Normally, one would also expect private millers to be guided by a profit-maximization goal. Furthermore, wages, interest rates, and prices for major foodstuff crops are regulated by the government. In effect, therefore, millers can reasonably be assumed to face an exogenous set of factor and output prices.

The miller's choice of technology problem and the level of efficiency and scale with which the chosen technology is operated can conveniently be analyzed within the production-function framework. The production function differs from the technological relation as expressed by equation [2] in that it presupposes technical efficiency and defines the maximum output obtainable from every possible input combination. The production function of each milling firm can be defined as

[3a] $Q = \mathrm{f}(X_1, X_2, X_3, ..., X_n, u)$

where Q is output and $X_1, X_2, ..., X_n$ represent different inputs necessary for the production of output Q; u is a random disturbance term representing factors such as unpredictable variations in machine or labour performance and other omitted variables.

For analytical convenience, the function $\mathrm{f}(Xi)$ is assumed to be single valued, continuous, and at least twice differentiable, thus ensuring marginal products that are positive and decreasing. That is,

[3b] $\mathrm{f}_x > 0, \mathrm{f}_{xx} < 0$

Given these assumptions, the miller can be said to choose along a continuum of production technologies so as to maximize profits (π) subject to the output constraint. Thus, the miller's decision problem can be summarized as:

maximize

[4a] $$\pi = PoQ - \sum_{i=1}^{n} Pi \cdot Xi$$

subject to

[4b] $Q = \mathrm{f}(Xi), i = 1, ..., \mathrm{n}$

where Po is output price and Pi the ith input price.

In what follows, the analysis focuses on four properties of the miller's production function that are considered relevant in explaining certain aspects of his technology choice. In particular, we are interested first in establishing the marginal productivity of each production input category ($f_{xi} = df/dXi$). To some extent, this measure provides us with some indications of the opportunity cost of that particular input and, when f_{xi} is compared with respective input prices, it gives indications of efficiency. Second, we wish to establish the specific effects of the technology-choice variables on output productivity. These effects enter the model through the production elasticities ($ni = f_{xi} \cdot (Xi/Q)$). Third, we will investigate the joint effects on output arising from the scale of operation or modification in technology, or both. These effects manifest themselves in form of returns to scale or scale elasticity ($\mu = \Sigma ni$), and may be constant ($\mu = 1$), decreasing ($\mu < 1$), or increasing ($\mu > 1$).

The absence of economies of scale could be an important factor in explaining the sheer survival of milling firms of different sizes in the grain-milling industry. If this is the case, then the cost advantage of larger-scale plants will not be all that commanding. Lastly, we focus on the elasticity of substitution (σ), which measures the ease with which inputs can be substituted for each other. This measure provides us with an important theoretical test to the existence of technology choice (i.e., when $\sigma > 0$).

As regards the specific functional form underlying the miller's production process, the Cobb–Douglas (C–D) production is initially assumed. A notable justification of this function is that it has proved to be a useful representation of most industrial production processes. An added advantage is that it can be handled with reasonable computational cost and manageability as it can be readily adapted into a linear framework. Furthermore, its wide application provides a base on which we can compare our own results. For estimation purposes, we impose a disturbance term (u) such that the production function becomes stochastic taking the form of

$$[5] \quad Q = A \cdot K^{\alpha} \cdot L^{\beta} \cdot e^{u}$$

which, in its log-linear specification, becomes

$$[6a] \quad \ln Q = \ln A + \alpha \ln K + \beta \ln L + u$$

where Q is output, K is capital, and L is labour. In this form, all partial, scale, and substitution elasticities are constant and, additionally, $\sigma = 1$. To allow for testing of a constant return-to-scale hypothesis, the C–D function is specified in the unrestricted form. Furthermore, we assume that the random disturbance term (u) is distributed independently of the levels of capital and labour inputs such that

$$[6b] \quad E(u) = 0; E(u^2) = \sigma^2; \text{ and}$$
$$E(u) \cdot \ln K = E(u) \cdot \ln L = 0$$

However, it is important to note that, whereas capital stock in form of equipment and structures may reasonably be assumed to be predetermined and unaffected by current fluctuations in output, the demand for labour is more likely to be vulnerable to changes in output levels. The latter case suggests the following additional equation to the model

$$[7] \quad L = \beta(Po/w) \cdot Qe^{\ddot{u}}$$

where Po is the price of output, W is the wage rate, and $\ddot{u}$ is another random disturbance term. To avoid simultaneity, a complete multiequational production decision model would have to be estimated provided good and consistent price-data series are available. Because we really do not have an adequate data base, we have used single equation methods to estimate equation [6a] alone using cross-sectional data. We have assumed that a possible simultaneous equation problem in estimation of equation [6a] can be ignored as unimportant.

The C–D function, however, does not shed much light on the factor-substitution issue because it assumes a unitary elasticity of substitution. To capture more explicitly this aspect, a constant elasticity of substitution (CES) function has also been fitted to the available data. A stochastic version of the generalized CES function may be expressed as

[8] $Q = A[\delta K^{-p} + (1 - \delta)L^{-p}]^{-v/p} \cdot l^{u}$
$(A > 0; 0 < \delta < 1; V > 0; p \geq -1)$

By taking logarithms of both sides of equation [8], we obtain

[9] $\ln Q = \ln A - v/\delta \cdot \ln[\delta K^{-p} + (1 - \delta)L^{-p}] + u$

where Q is output, K is capital, L is labour, A is the efficiency parameter, v is the returns-to-scale parameter, δ is the distribution parameter, p is the substitution parameter, and u is the disturbance term.

As presented in equations [8] and [9], the CES function is arduous to estimate because it cannot be transformed to a function linear in parameters. As alternatives, two more manageable CES forms have been tried. One is the indirect Arrow, Chenery, Minhas, and Solow (ACMS) equation (Arrow et al. 1961) whereby the elasticity of substitution (σ) is estimated from the marginal productivity relation:

[10] $\ln(Q/L) = a + \sigma \cdot \ln w$

where Q is real output, w is the real wage rate, L is labour, and $a = \ln a$. This form is easy to estimate because σ enters into it as a first-order parameter. Its limitation, however, arises from additional rather strong assumptions is imposes on the underlying structure. In particular, its valid application requires ideal profit-maximization conditions, constant returns to scale, and availability of good input-price data with significant price dispersion.

In view of these problems, a more direct estimation of CES function has been undertaken using Kmenta's linear approximation method. This is based on a second-order Taylor-series expansion of the logarithm of the function [9] around $p = 0$, thus obtaining

[11] $\ln Q = \ln A + v \cdot \delta \cdot \ln K + v(1 - \delta)\ln L - 0.5 \cdot pv\delta[\ln K - \ln L] + u$

which, in its unrestricted form, can be estimated by

[12] $\ln Q = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_3(\ln K - \ln L)^2 + u$

Two interesting features of this specification are worth mentioning. One is that this approximation is not a constant elasticity form and, second, it provides us with a direct test of the C–D form. Thus, if $p = 0$, the term $\beta_3(\ln K - \ln L)^2$ will disappear, reducing the relation in function [12] to the C–D form. Consequently, if β_3 is significantly different from zero, the C–D relation is rejected.

As presented above, both the C–D and CES functional forms are homothetic and the corresponding elasticities depend upon the ratio of the two inputs. An attempt to test for the existence of nonhomotheticity has also been made. This aspect is considered important because existence of a homothetic production relation would imply that, for a given technology, the employment-generating effects of increased output would be limited by the underlying technology. This may be true even if the wage rate does not rise. By expanding the square term in function [12], we can obtain a more flexible functional form

$$[13] \quad \ln Q = \beta_0 + \beta_1 \ln K + \beta_2 \ln L + \beta_{31}(\ln K)^2 - 2\beta_{32}(\ln K \cdot \ln L) + b_{33}(\ln L)^2 + u$$

This form, which is commonly known as the translog function (see, for example, Christensen et al. (1971) who present an illuminating theoretical exposition on this), is flexible in the sense that it does not impose either the constant elasticities or the homotheticity assumption on the underlying technology. Alternatively, testing for nonhomotheticity can be achieved by estimating the C–D function for subsamples and then allowing various parameters to vary across size categories.

Appendix II: Assumptions on the benefit–cost analysis

In carrying out project evaluations of alternative technologies several assumptions have been made.

First, as explained in Chapter Five, it has not been useful to compare benefit–cost ratios of custom and merchant mills. Each sector is assumed to operate in a markedly different environment and to produce a distinct product. All maize custom mills are assumed to produce one homogeneous product — maize whole meal. Also, although maize merchant mills can, in principle, produce two grades of sifted maize meals, only the standard sembe grade has been assumed in this analysis. This makes sense because, in practice, it is the only grade currently being produced. For analytical convenience, it has also been assumed that differences in milling properties associated with different varieties of maize are negligible.

Second, the evaluation is based on the existing milling technologies currently in use and does not examine other potential milling equipment options that could be open to a Tanzanian investor. The inclusion of the latter aspect would have necessitated collection of cross-country data — a task that this study could not easily handle given the limited time and resources available. Moreover, a study that examines alternative options (based on evaluation of worldwide representative model factories) has already been undertaken by Uhlig and Bhat (1979).

Third, this appraisal uses current-factor prices rather than expected future prices. Although some investors may be guided by future factor prices in their investment decisions, there is no strong basis for assuming different rates of inflation of different factor inputs. It is, thus, assumed that the effect of inflation is symmetrical on all factor inputs.

The fourth assumption concerns the costs taken into account when comparing technologies. The major costs taken into account are those of labour, capital (equipment and building as well as the cost of operating capital), raw grains, packing materials, energy, spares, and maintenance costs. Overhead costs have been omitted partly because of inadequate information and partly because they tend to be invariate within each technology category.

Transport and distribution costs have also been excluded from the analysis. This is because, in practice, custom mills serve customers in the vicinity and do not distribute final products. For merchant mills, the transport of raw grains is undertaken centrally by the transport section of the National Milling Corporation (NMC) to the milling plant. Milled products are also sold ex-mill: wholesalers (i.e., National Distributors, Regional Trading Corporations, and other authorized large retailers) collect the product themselves at the factory gate.

The final assumption relates to sets of prices used. For market prices, the study uses current (1983) Tanzanian factor prices. However, as pointed out in Chapter Five, there are good reasons to believe that, in Tanzania, capital is undervalued, and both unskilled labour and the domestic currency overvalued. In such circumstances, the use of market prices in project evaluation would tend to generate misleading estimates. Furthermore, it has been pointed out that merchant mills do not operate on a competitive basis and that the prices they charge are set by the government. Also, although there is an element of competition among custom mills, this competition is not absolute. In some rural areas, for example, custom mills act as monopolies. Local governments may also intervene by setting up a maximum milling fee to be charged by custom millers. Consequently, the value added generated by the grain-milling firms can not be taken as a reliable indicator of the social value added.

To correct some of the biases arising from factor-market distortions, I have used the rule of thumb to adjust market prices for major inputs and output to conform more closely to social evaluations. The resulting "corrected" or "accounting" prices are not ideal "shadow" prices in the sense that they have not been derived from the solution of a general equilibrium mode (Scott et al. 1976). The accounting price for unskilled labour has been set at its marginal (value) product obtaining in the custom-milling sector. This worked out to be 85% of the sector's average worker's monthly wage, actually paid. Unfortunately, the lack of relevant data on consumption patterns prevented any evaluation on skilled labour that has been priced at its cost.

Milling equipment has been valued at CIF (cost, insurance, and freight) prices at the border. Building costs account for 40 and 30% of total fixed capital cost in custom and merchant mills respectively. Half of the building costs are estimated to be composed of labour costs. The labour component of the building has thus been adjusted to an economic value through the use of the shadow wage rate. The remaining cost component of buildings has been valued at its market cost.

The absence of international trade in milled maize flour makes it difficult to obtain estimates of social value added. However, because about 94.0 and 97.5% of total raw material cost in merchant mills is the cost of raw maize and paddy respectively and because prices of domestic maize and rice were on average 50 and 20% higher than the corresponding import prices, adjusted value added (value added at world market prices) has been obtained by dividing the value added at market prices by 1.423 (= 45% of 94%) in the case of maize and 1.195 (= 20% of 97.7%) in the case of rice. The same is applied for value added generated by custom mills.

The exchange rate adjustment was made by assuming 1970 as a year with reasonable exchange rate parity. The nominal exchange rate was 7.14 TZS/USD in 1970, and moved up to 11.72 TZS/USD in 1983. The ratio of Tanzania's price level to that of its major trading partners was 2.12 in 1983 (Naho 1986). Thus, the purchasing power parity should have been 15.14 TZS (= 2.12 × 7.14 TZS) per USD. The actual rate thus over-valued the shilling by about 30%. The exchange rate used in social cost–benefit analysis is 15.14 TZS/USD. Finally, the social rate of return on capital investment has been estimated at 15% per year. This is line with the Tanzanian Government policy, which normally ensures a 15% return on capital employed for new industrial projects.

The appropriate discount rate is somewhat more difficult to establish. Survey responses indicated that some custom millers borrowed funds from informal sources at twice the official lending rates (i.e., at about 25%). Although such rates suggest some form of capital market fragmentation, they do not necessarily reflect real costs of borrowing funds as they are not, for example, adjusted for default risk. We have, therefore, used a discount rate of 15% to approximate the opportunity cost of capital. As indicated earlier (Chapter Three), the Tanzanian Government policy stipulates a 15% return on capital employed for new industrial projects. We suspect, however, that this discount rate is somewhat low and would give the benefit of the doubt to less labour-intensive mills. The 15% discount rate was also used to convert working capital stock into cost of operating capital.

Appendix III: Marginal productivity of labour and capital

Mill type and productivity (tonnes/day)	Labour: Average productivity[a]	Labour: Elasticity	Labour: Marginal productivity[a]	Capital: Average productivity[b]	Capital: Elasticity	Capital: Marginal productivity[b]
Maize hammer						
6	0.08	0.62	0.050	0.19	0.41	0.078
22	0.14	0.62	0.087	0.16	0.41	0.066
Maize roller						
24	0.15	0.52	0.078	0.02	0.33	0.007
50	0.17	0.52	0.088	0.013	0.33	0.004
120	0.19	0.52	0.099	0.012	0.33	0.004
Rice huller	0.13	0.62	0.081	0.167	0.41	0.068
Rice roller						
24	0.14	0.52	0.073	0.022	0.33	0.007
60	0.16	0.52	0.083	0.018	0.33	0.006
120	0.18	0.52	0.094	0.018	0.33	0.006
Custom mill[c]	0.097	0.620	0.060 (720)[d]	0.173	0.410	0.071
Merchant mills[c]	0.165	0.520	0.086 (1 630)	0.017	0.330	0.006

Source: Survey data, Table 11.
[a] Tonnes/person-hour.
[b] Tonnes/TZS invested.
[c] Subsectoral weighted averages.
[d] Values in parentheses are marginal products per month assuming mean monthly hours of 100 and 150 in custom and merchant milling subsectors respectively.

Appendix IV: Average annual costs (000 TZS)

Part a: Custom mills.

	Assumed capacity[a]	Spares and maintenance	Power	Capital Working	Capital Fixed	Labour
Hammer mill (6 tonnes/day)						
Electric						
Import	A	13.6	29.7	2.0	25.3	40.5
	B	16.3	38.6	2.0	25.3	50.1
	C	13.5	29.6	2.0	25.3	40.5
Local	A	14.0	35.0	2.2	27.4	34.4
	B	16.3	38.6	2.0	27.4	50.1
	C	14.0	35.2	2.0	27.4	34.4
Diesel						
Imported	A	14.2	39.8	1.5	30.5	34.7
	B	15.0	47.8	2.0	30.5	50.1
	C	14.2	39.8	1.5	30.5	34.7
Local	A	13.0	37.2	1.4	31.5	25.8
	B	15.0	47.8	2.0	31.5	50.1
	C	13.0	37.1	1.4	31.5	25.8
Hammer mill (22.5 tonnes/day)						
Electric						
Imported	A	50.0	105.0	25.0	44.3	95.0
	B	60.0	126.0	25.0	44.3	106.4
	C	50.0	83.7	25.0	44.3	95.5
Local	A	49.5	101.8	30.0	45.6	101.0
	B	60.0	126.0	30.0	45.6	104.4
	C	49.5	81.8	30.0	45.6	90.4
Rice huller (6 tonnes/day)						
Electric						
Imported	A	13.5	30.0	2.0	20.0	25.0
	B	17.6	39.0	2.0	20.0	37.5
	C	13.5	35.0	2.0	20.0	25.0
Diesel						
Imported	A	13.2	33.0	2.0	22.0	25.0
	B	17.5	42.9	2.0	22.0	37.5
	C	13.2	33.7	2.0	22.0	25.1

Source: Survey data.

[a] Level of capacity utilization: A = Existing (actual) level of capacity utilization, B = Full capacity utilization, and C = 50% capacity utilization.

Appendix IV continued.

Part b: Merchant mills.

Mill type and capacity (tonnes/ day)	Assumed capacity[a]	Grain cost	Packing material	Spares and maintenance	Power	Capital		Labour cost
						Working	Fixed	
Maize roller								
24	A	25 576	1 303	82.4	188.0	23.6	397.5	201.5
	B	33 657	1 713	82.4	247.4	23.6	397.5	250.7
	C	16 828	856	74.4	157.3	23.6	397.5	225.6
50	A	60 200	3 066	117.8	403.5	65.3	993	615.0
	B	70 000	3 561	111.8	469.5	65.3	993	615.0
	C	35 000	1 780	117.8	247.1	65.3	993	584.2
120	A	81 993	4 177	177.9	826.5	167.6	1 400	905.0
	B	113 898	5 794	177.9	1 147.0	167.6	1 400	905.0
	C	56 949	2 897	177.9	591.2	167.6	1 400	859.7
Rice roller								
24	A	42 438	819	51.4	195.0	41.7	265.3	194.3
	B	80 076	1 545	51.4	195.0	41.7	265.3	194.3
	C	40 038	773	51.4	190.6	41.7	265.3	180.0
50	A	101 917	1 967	105.0	405.0	77.1	669	435.1
	B	167 085	3 225	105.0	664.7	77.1	669	435.1
	C	83 543	1 612	105.0	339.8	77.1	669	430.0
120	A	171 138	3 303	178.5	759	180.5	1 203	851.7
	B	295 057	5 694	178.5	1 308.7	180.5	1 203	851.7
	C	147 528	2 847	178.5	664	180.5	1 203	723.0

Source: Survey data, National Milling Corporation.
[a] As in Appendix IV(a).

Appendix V: Average annual output, sales, value added, labour and capital costs

Part a: Custom mills.

	Assumed capacity[a]	Output (tonnes)	Sales (TZS 000)	Material costs (TZS 000)	Value added (TZS 000)	Labour costs (TZS 000)	Surplus (TZS 000)	Capital costs (TZS 000)
Hammer mill (6 tonnes/day)								
Electric								
Imported	A	625	125	45.3	79.7	40.5	39.2	25.3
	B	1 250	250	56.9	193.1	50.1	143.0	25.3
	C	625	125	45.1	79.9	40.5	39.4	25.3
Local	A	660	132	51.2	80.8	34.4	46.4	27.4
	B	1 250	250	56.9	193.1	50.1	143.0	27.4
	C	625	125	51.2	73.8	34.4	39.4	27.4
Diesel								
Imported	A	655	131	55.5	75.5	34.7	40.8	30.5
	B	1 250	250	64.8	185.2	50.1	135.1	30.5
	C	625	125	55.5	69.5	34.7	34.8	30.5
Local	A	550	110	51.6	58.4	25.8	32.6	31.5
	B	1 250	250	64.8	185.2	50.1	135.1	31.5
	C	625	125	51.5	73.5	25.8	47.7	31.5
Hammer mill (22.5 tonnes/day)								
Electric								
Imported	A	2 420	484	180	304.0	95.0	209.0	44.3
	B	3 720	744	211	533.0	106.4	426.6	44.3
	C	1 860	372	158.7	213.3	95.5	117.8	44.3
Local	A	2 450	490	181.3	308.7	101.0	207.7	45.6
	B	3 720	744	216.0	528.0	104.4	423.6	45.6
	C	1 860	372	161.3	210.7	90.4	120.3	45.6
Rice huller (6 tonnes/day)								
Electric								
Imported	A	625	122.5	45.5	77.0	25.0	52.0	20.0
	B	1 607	315.0	58.6	256.4	37.5	218.9	20.0
	C	803	157.5	50.5	107.0	25.0	82.0	20.0
Diesel								
Imported	A	625	122.5	48.2	74.3	25.0	49.3	22.0
	B	1 607	315.0	62.4	252.6	37.5	215.1	22.0
	C	803	157.5	48.9	108.6	25.1	83.5	22.0

Source: Survey data, National Milling Corporation.
[a] Assumed capacity: A = current capacity, B = 100%, and C = 50%.

Appendix V continued.

Part b: Merchant mills.

Mill type and capacity (tonnes/ day)	Assumed capacity[a]	Output (tonnes)	Sales (TZS 000)	Material costs (TZS 000)	Value added (TZS 000)	Labour costs (TZS 000)	Surplus (TZS 000)	Capital costs (TZS 000)
Maize roller								
24	A	5 310	27 777	27 173	604	202	403	398
	B	7 015	36 698	35 723	975	251	724	398
	C	3 508	18 349	17 939	410	226	184	398
50	A	12 545	65 625	63 853	1 772	615	1 157	993
	B	14 589	76 309	74 214	2 045	615	1 480	993
	C	7 293	38 152	37 210	915	548	358	993
120	A	17 089	89 387	87 342	2 045	905	1 140	1 400
	B	23 736	124 163	121 185	2 979	905	2 074	1 400
	C	11 868	62 081	60 783	1 298	860	439	1 400
Rice roller								
24	A	3 666	43 991	43 545	446	194	252	265
	B	6 918	83 021	81 909	1 112	194	918	265
	C	3 459	41 511	41 095	416	180	236	265
60	A	8 805	105 667	104 471	1 196	435	761	669
	B	14 435	173 231	171 157	2 074	435	1 639	669
	C	7 218	86 615	85 647	938	430	508	669
120	A	14 785	177 424	175 559	1 865	852	1 013	1 203
	B	25 492	305 909	302 419	3 490	852	2 639	1 203
	C	12 747	152 961	151 398	1 563	723	840	1 203

Source: Survey data, Appendix V, National Milling Corporation.

[a] As in Appendix V(a).

Appendix VI: Average annual value added, labour, and capital costs

Part a: Custom mills.

	Assumed capacity	Value added (TZS 000)	Labour costs (TZS 000)	Surplus (TZS 000)	Capital costs (TZS 000)	Benefit–cost ratio
Hammer mill (6 tonnes/day)						
Electric						
Imported	A	56.0	34.4	21.6	29.1	0.74
	B	135.7	42.6	93.7	29.1	3.22
	C	56.1	34.4	21.7	29.1	0.75
Local	A	56.8	29.2	27.6	28.5	0.97
	B	135.7	42.6	93.1	28.5	3.27
	C	51.9	29.2	22.7	28.5	0.80
Diesel						
Imported	A	53.1	29.5	23.6	33.9	0.70
	B	130.1	42.6	87.5	33.9	2.58
	C	48.8	29.5	19.3	33.9	0.57
Local	A	41.0	21.9	19.1	32.8	0.58
	B	130.1	42.6	87.5	32.8	2.67
	C	51.6	21.9	19.1	32.8	0.91
Hammer mill (22.5 tonnes/day)						
Electric						
Imported	A	213.6	80.8	132.8	50.9	2.60
	B	374.6	90.1	284.5	50.9	5.59
	C	149.2	81.2	68.0	50.9	1.33
Local	A	216.9	85.9	131.0	47.4	2.76
	B	429.3	88.7	340.6	47.4	7.18
	C	148.1	76.8	71.3	47.4	1.50
Rice-huller (6 tonnes/day)						
Electric						
Imported	A	64.4	21.2	43.2	23.0	1.88
	B	214.6	31.9	182.7	23.0	7.94
	C	75.2	21.2	54.0	23.0	2.35
Diesel						
Imported	A	62.2	21.2	41.0	25.3	1.62
	B	210.9	31.9	179.0	25.3	7.07
	C	90.9	21.2	70.7	25.3	2.79

Source: Survey data.
[a] At shadow prices.

Appendix VI continued.

Part b: Merchant mills.

	Assumed capacity	Value added (TZS 000)	Labour costs (TZS 000)	Surplus (TZS 000)	Capital costs (TZS 000)	Benefit–cost ratio
Maize roller						
24	A	425	181	243	473	0.51
	B	685	226	459	473	0.97
	C	288	203	85	473	0.18
50	A	1 246	554	692	1 182	0.59
	B	1 473	554	919	1 182	0.78
	C	661	526	136	1 182	0.11
120	A	1 437	815	623	1 666	0.37
	B	2 093	815	1 279	1 666	0.77
	C	912	774	139	1 666	0.08
Rice roller						
24	A	373	175	198	316	0.63
	B	904	175	796	316	2.52
	C	348	162	186	316	0.59
60	A	840	392	449	796	0.56
	B	1 736	392	1 344	796	1.69
	C	785	387	398	796	0.50
120	A	1 561	767	884	1 432	0.62
	B	2 921	767	2 154	1 432	1.50
	C	1 308	651	657	1 432	0.46

Source: Survey data; National Milling Corporation.

Appendix VII: Estimates of elasticity of substitution using Kmenta's method

	O	$\ln K_u$	$\ln L$	$(\ln K_u - \ln L)^2$	R^2	F-value
1982	−1.988	−0.364	1.357	−0.194	0.961	495.8
	(1.510)[a]	(0.605)	(0.645)			
1983	−1.826	−0.355	1.333	−0.191	0.958	465.0
	(1.524)	(0.612)	(0.651)	(0.164)		
Pool	1.881	−0.345	1.332	−0.188	0.959	989.2
	(1.051)	(0.421)	(0.449)	(0.114)		

Source: Survey data.

[a] Values in parentheses refer to the standard errors of the estimates.

Appendix VIII: Production functions for custom and merchant mills

	$\ln A$	$\ln K_u$	$\ln L$	R^2	F-value
1982					
Custom	−2.921	0.436	0.625	0.816	108.4
	(0.633)[a]	(0.102)	(0.129)		
Merchant	−0.519	0.428	0.370	0.928	81.82
	(1.157)	(0.290)	(0.419)		
1983					
Custom	−2.451	0.425	0.582	0.798	96.81
	(0.628)	(0.100)	(0.121)		
Merchant	−1.113	0.236	0.656	0.926	62.82
	(1.313)	(0.304)	(0.454)		
Pool					
Custom	−2.651	0.407	0.625	0.794	194.209
	(0.454)	(0.072)	(0.089)		
Merchant	−0.807	0.325	0.520	0.920	144.7
	(0.808)	(0.191)	(0.281)		

[a] Values in parentheses refer to the standard errors of the estimates.

Appendix IX: Translog production function

O	ln$K$	ln$L$	(ln$K$)^2	ln$K$·ln$L$	(ln$L$)^2	R^2	F-value
12.881	2.240	-3.604	0.017	-0.232	0.629	0.961	618.7
(5.762)[a]	(1.347)	(2.043)	0.257)	(0.372)			

[a] Values in parentheses refer to the standard errors of the estimates.

Appendix X: National Milling Corporation (NMC) purchases of main staples (000 tonnes), 1971–72 to 1988–89

Year	Maize	Rice[a]	Wheat	Cassava	Millet and sorghum	Beans	Total
1971–72	43	45	57	—	—	—	145
1972–73	96	47	51	14	1	—	209
1973–74	74	39	28	19	2	—	162
1974–75	24	15	14	18	2	—	73
1975–76	91	12	24	17	4	—	148
1976–77	127	15	27	20	16	11	216
1977–78	213	35	35	37	48	31	399
1978–79	220	34	29	64	75	28	450
1979–80	161	30	27	44	22	34	318
1980–81	105	13	28	7	21	16	190
1981–82	89	15	23	9	11	14	161
1982–83	86	21	31	19	5	11	173
1983–84	71	22	28	31	5	8	165
1984–85	85	12	33	20	2	4	156
1985–86	178	16	50	13	15	6	278
1986–87	173	11	34	14	6	29	267
1987–88	229	43	43	9	6	35	365
1988–89[b]	110	45	44	—	—	2	201

Source: Market Development Bureau.

Note: In 1985–86, cooperative unions were reinstated and NMC was no longer monopoly buyer.

[a] Paddy converted to rice equivalent.

[b] Purchases as at 3 February 1989.

Appendix XI: National Milling Corporation imports of maize, paddy, and wheat (000 tonnes), 1975–76 to 1988–89

	Maize	Rice	Wheat[b]
1975–76	106.5	20.8	60.2
1976–77	41.6	5.3	33.6
1977–78	34.3	48.1	40.5
1978–79	—	41.2	61.3
1971–80	32.5	54.7	32.5
1980–81	274.6	65.2	48.7
1981–82	231.6	66.5	70.9
1982–83	123.4	29.4	11.4
1983–84	194.3	57.1	46.3
1984–85	128.5	36.1	33.4
1985–86	6.1	32.9	21.8
1986–87	93.6	63.5	53.5
1987–88	85.0	44.5	33.7

Source: Marketing Development Bureau.

[a] Includes both commercial and aid imports.

[b] Includes both grain and flour.

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