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APPROPRIATE TECHNOLOGY FOR THE PRODUCTION OF TEXTILES

PRODUCTION OF COTTON CLOTH

Background Paper

PRODUCTION OF COTTON CLOTH

by

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This paper is placed firmly in the context of the employment problem and, in this light, that of designing industrial policies which will simultaneously produce economic growth and satisfy basic needs. In this connection a distinction is drawn between rural and urban areas, the former being areas of relatively low cost labour, negligible infrastructure and limited local markets, and hence being more appropriate for labour-intensive, small-scale industry than for large-scale activities.

The satisfaction of basic needs involves the provision of purchasing power - normally in developing country conditions through employment - and goods which are within range of that power. Clothing of a plain kind is clearly what can be described as a basic needs commodity; and grey cotton cloth is a basic element in the production of clothing. This justifies the subsequent emphasis on cotton cloth production. That a commodity has the property of being able physically to meet a basic need does not necessarily mean that its production - with particular reference to scale, employment and location - can be readily organized to generate directly the purchasing power required for its acquisition. A consequent, important purpose of the paper is to probe the possibilities in this regard for cotton cloth.

In poor countries it is important that productive activities should generate a surplus which, in principle, contributes to future economic growth and development. It is also desirable that as much employment as possible be provided consistent with the generation of a surplus and that there should be as much flexibility as possible in the size and location of production units. There is, of course, no necessary match between markets and factories, so that in principle a highly segmented market could be served by a single factory and a concentrated market by a large number of factories. Again, however, there is at least a presumption in favour of the desirability of relatively small-scale, labour-intensive and dispersed factories serving local markets.

Broadly the surplus is the difference between the revenues resulting from effective demand and the operating and capital costs of production. The costs in turn are largely a function of the technology employed since - granted that raw material, land and utility costs are invariant - costs will differ according to the proportions in which men and machines are employed, the amount of space required, energy needed and the efficiency with which the raw material is transformed into a finished product. Given a profitability constraint it follows from this that technology and technology options form the main limiting factor on the flexibility identified above as being desirable. It further follows that a serious industrial policy in the context of basic needs can only be predicated on a detailed and careful analysis of technological alternatives. A consequent ambition of the present paper is to illustrate how this may be done.

The remainder of the paper is organized in three parts. The first considers briefly world production and trade in textiles and textile machinery; the second gives some details of the structure and character of textile production; and the third provides the results of economic evaluation and draws policy conclusions from these. One feature of the paper which should be explicitly mentioned is that particular emphasis is placed on African conditions.

(1) World Production and Trade

Production of woven cotton cloth in developing countries rose from an average annual level of 17.7 thousand million square metres in the period 1966-1968 to 19.3 million square metres in the period 1973-1975. Over the same years average annual woven cotton cloth production in the developed market economies of the world fell from 37.4 to 34.0 thousand million square metres. As a result of these respective changes the share of developing countries in total output rose from 47 to 57 per cent. The share of developing countries in world production of synthetic cloth is much smaller than in cotton textiles. Nevertheless it increased from 5 per cent (130 million square metres) to 12 per cent (690 million square metres) in the period considered.

Developing countries accounted for 34 per cent of world exports of cotton cloth in the years 1973-1975 compared with 29 per cent in 1967-1969. In the later period (as in the earlier one) the developing countries contributed relatively more to exports of grey than to finished cloth - with the respective shares being 64 and 27 per cent. The share of the developing countries in world exports of non-cotton cloth, including cellulosics, showed little change over the period and was about 13 per cent. Their share of world exports of yarn was about 25 per cent for cotton and 4 per cent for synthetic yarn.

As would be expected developing countries contributed relatively little to exports of textile machines - 0.9 per cent in 1967-1969 and 1.8 per cent in 1973-1975. They did, however, represent a relatively large market for such equipment and the proportion of world imports sold in such countries rose from 30 per cent in 1967-1969 to 38 per cent in 1973-1975.

Clothing manufacture is outside the scope of this paper. For completeness, however, it may be observed that while this is relatively important in the domestic markets of developing countries, it is - in suitable styles - a highly developed export trade contributing in 1973-1975 some US $3.3 thousand million net to exports. This may be compared with exports of yarn and fabric of natural fibre which contributed US $0.6 thousand million to net exports. If man-made fibre manufactures are included, then the trade balance on yarn and fabric becomes negative at about US $1.1 thousand million net.

(2) The Structure and Character of Textile Production

The above trade figures reflect the general nature of the textile activities undertaken in developing countries. Finishing is less developed than weaving while clothing manufacture is growing steadily in importance - largely as a consequence of the relatively labour-intensive nature of the clothing industry and of the relatively small scale at which it can be efficiently conducted. For reasons given earlier, however, and to keep the scope of the paper from becoming too wide, it is nevertheless still convenient largely to confine it to cotton cloth.

In this regard the main task is to elucidate those characteristics of the structure and methods of production which bear on the choice of scale, location and technology. To this end it is convenient first to consider market size - since this is frequently linked to technical economies of scale in discussions of the present kind - and thereafter to examine the relationships between such economies and efficiency more specifically. It is further convenient then to specify machine choices and to describe the main stages in cotton cloth production with a brief mention of the alternatives at each stage. This procedure both sets the stage for economic evaluation and facilitates the discussion of policy alternatives. Not all of the material present below is used subsequently, so that a subsidiary aim of this part of the paper is to provide some background information that could be useful in a more extensive search for suitable technologies.

(i) Market Size

The relationship between market and domestic textile industry size is documented in Table 1.

TABLE 1

Domestic Production and Size of Market
in African Countries
(in million square metres and percentages)

	Domestic market for woven cotton and man-made fibre cloth (Annual Average 1970-1971 to 1974-1975) (1)	Production of woven cotton and man-made fibre cloth for the domestic market (Annual Average 1970-1971 to 1974-1975) (2)	Share of domestic production in domestic consumption (2÷1 as percent) (3)
Egypt	902 (1)[a/]	718	80 (1)[a/]
Nigeria	396 (2)	264	66 (2)
Sudan	271 (3)	96	35 (15)
Morocco	133 (4)	86	65 (10)
Algeria	128 (5)	80	62 (9)
Zaire	113 (6)	62	55 (12)
Tanzania	102 (7)	78	77 (5)
Ghana (1968/72)	95 (8)	49	51 (13)
Ethiopia	90 (9)	80	88 (4)
Madagascar	81 (10)	72	90 (3)
Uganda	53 (11)	40	76 (6)
Angola	52 (12)	20	38 (16)
Senegal	50 (13)	9	18 (21)
Mozambique	43 (14)	19	44 (17)
Tunisia	33 (15)	23	70 (7)
Zambia	32 (16)	12	37 (18)
Togo	28 (17)	10	35 (19)
Niger	28 (18)	11	39 (14)
Somalia	26 (19)	3	19 (20)
Chad	20 (20)	12	60 (11)
Central African Empire	12 (21)	8	67 (8)

Source: UN Yearbook of Industry Statistics, 1975, Vol.2 and Yearbook of International Statistics, 1976, Vol.1.

a/ Rank ordering in brackets.

Although the correlation is not perfect, it is broadly true that the larger the market the larger the share held by the domestic industry. Thus for the eleven largest markets the median share is 60 per cent and for the eleven smallest it is 39 per cent. There are some anomalies - the proportion in Sudan is low but there has been considerable development there since 1975; that in Tunisia is high, possibly because of the importance of exports; and the high figures in Chad and Central African Empire may be partly due to large supplies of locally grown cotton in contrast to the position in, say, Somalia and Senegal.

It is tempting to conclude from the data of Table 1 that, on the basis of African experience, there is an important link between market size and efficiency. Rigorously speaking, this is no doubt so. It would, however, be wrong to pre-judge the extent to which this represents a binding constraint - particularly since past decisions on size and technology were taken on the basis of a conventional wisdom which thought it desirable uncritically to transfer technology from developed to developing countries. It is thus necessary to consider technical economies and efficiency in somewhat more detail.

(ii) Technical Economies and Efficiency

As a general rule, producing for a small market tends to be uneconomical either because the capacity of certain machines in the production process is too great in relation to the volume of demand for them to be fully utilized or because a sufficient volume can only be achieved by accepting an unduly wide range of products and, therefore, of short runs. This capacity constraint need not, of course, operate uniformly at all stages of the production process.

In textile spinning and weaving, the key machines - spindles and looms - are individually of small capacity and the only large capacity machines in the entire process are in the opening range of the spinning process and in the warping and slashing stages of the weaving process. Thus, the conventional ring spinning sequence involves an opening range with a capacity equal to that of 10,000 spindles on 20's counts (or for a balanced cloth about 750 automatic looms) and scutchers with half that capacity. The conventional weaving preparation involves a warping machine with a capacity at 50 per cent efficiency equal to that of about 1500 automatic looms and a sizing machine with a capacity of about one half of this.

These figures determine the minimum size of plant necessary fully to utilize capacity. As, however, the data in Table 2 shows, the costs of the 'constraining' machines are so small in relation to that of spinning and weaving that working to less than capacity could readily be economically tolerated, since - when overall capacity is matched to that of the opening line - the relevant proportion is less than 8 per cent. Moreover, even if the spinning and weaving capacity were reduced to one-quarter of the level assumed in the table, the spinning and weaving machinery would still cost more than twice as much as the other equipment covered by the table.

TABLE 2

Manning and Machine Cost of Certain Textile Machines under Medium-Wage[a/] African Conditions

	Number of machines	Capital cost (1976 prices) (US $000)	Manning
Opening line	1	200	8
Scutcher	2	80	2
Ring spindles	16,000	1840	30
Warping	1	80	6
Sizing	1	100	6
Looms	800	4000	160
Total Costs and Manning		6300	212

a/ See below for fuller specification of medium-wage regime.

In finishing, however, a distinction has existed for some time between continuous process and batch processing machines, the former being of much larger capacity. The roller printing machine has an output, when running, equal to that of about 600 looms, but screen printing and, at a higher level of output, mechanized screen printing are small scale alternatives. Similarly the normal dyeing vessel (jig) has a capacity of about 1000yards of cloth while continuous dyeing at 70 yards a minute has a capacity equal to that of 800 looms, and the modern stenter a capacity equal to that of 1200 looms.

The actual output of a machine depends on its speed, the time it is running - length of run - and the time required to set it up. For continuous processing machines high speeds and long setting up times are the rule. For machine printing setting up time apart from the time needed to engrave the rollers may range from 1 to 8 hours according to the complexity of the design and similarly the average time needed to set up continuous dyeing is about 4 hours. Long runs are, therefore, necessary for economic performance and finishing works are normally associated with large-scale production. Usually in a large market a single finishing works takes the output of several weaving plants, while in small markets where demand may be as little as 1000 yards per style the jig is the standard machine.

The time required to set up spinning and weaving activities is much smaller than that involved in continuous finishing and short runs can thus be accommodated more readily. In weaving, the warp on a weaver's beam may average 3000 yards - about 600 loom-hours on automatic looms and 1000 on ordinary looms. These figures indicate the length of the run between drawing in or knotting the new warps. The drawing in process if done manually might employ two persons for 5 hours. With Sulzer looms however the time for drawing in is several times longer although this would be cut by automatic drawing in. If variety is such that a new sized warp is required at the beginning of each run, then the minimum run is about six times as long so that with setting up time of 2½ hours the normal efficiency of operation will be about 50 per cent.

In spinning a change of count is a small matter unless a change of roving or still more of mixing is involved. Changes at the winding stage however can cause long delays reducing efficiency to 75 per cent if automatic winders are involved.

The saving of time involved in adjusting machines is only one advantage of long runs. Greater advantages are probably obtained from the reduction in administrative and clerical expenses, which in developing countries average about 10 per cent of total costs, and in the holding of stocks of materials and accessories. More generally if a high degree of specialization can be realized the deployment of labour; capital and raw material can be optimized, thus work loads and incentives can be established and raw material and machine usage more closely related to production.

(iii) Machine Availability

Turning now to machine availability, technical progress in textile machinery (in particular in spinning and weaving) has increased the speed and degree of automation of conventional equipment. The increase in speed has saved capital in some cases and automation has invariably saved labour - especially skilled labour since automated machines may be staffed by relatively unskilled operatives and few skilled engineers.

Moreover new techniques of spinning and weaving have been discovered which have greatly increased productivity. Thus the latest model carding engine has ten times the output per attendant of the 1955 model and also costs less per unit of output. In spinning the modern ring spindle has an output about 50 per cent greater than that of twenty years ago while the open end rotor on 20's counts costs twice as much as a ring spindle per unit of output but requires only half the labour. In weaving the modern automatic loom has an output for the latest model about 40 per cent above that of twenty years ago and requires 25 per cent less labour, while shuttleless looms have outputs up to three times that of shuttle looms and cost about 50 per cent more per unit of output.

In general therefore the machine choice is between capital saving and labour saving although in some cases like that of the carding engines the modern machine saves both and is therefore more efficient. It may also be the case that after an initial proving period some of the more recent developments such as open-end spinning may turn out to have a lower long term cost of production than more conventional machines. Within the present framework however the choice of machine appropriate to a low wage country would be different from that appropriate to a high wage one and similarly large capacity machines which might be appropriate to a large market would not be so for a small market. It might also be appropriate to obtain machinery from India or China where all but the latest high speed, high capacity models are available at prices considerably below those of Western suppliers. Moreover where wages are low and markets small, hand spinning and weaving equipment can also be reasonably considered.

(iv) Textile Manufacturing Processes

Textile manufacture consists of a number of successive processes in each of which alternative technologies are available. Limiting consideration to the production of woven cotton cloth the following stages may be distinguished:

(i) Opening and cleaning of raw cotton: The object of this process is to blend cotton so as to get a uniform raw material, remove leaf dirt and trash, open up the fibres after these have been compressed in the bale and deliver a cleaned uniform product in a suitable form to the next stage. The process begins with feeding of cotton which may be manually or mechanically plucked from the bales and ends with the scutcher which either forms a lap (which is then either manually or automatically doffed) or chute feeds the material to the next stage. The modern opening line has a capacity of about 1200 lb an hour and 600 lb an hour for the scutcher. The small scale machine used for hand spinning has a capacity of about 8 lb an hour and the associated lap formers about 2½ lb an hour.

In total, therefore, there are 6 large scale and one small scale alternatives which can be used at this stage;

(ii) Carding: Here the aim is to attenuate the lap into a sliver - about 100 draft - and arrange the fibres in a parallel way for the next stage. As indicated above the modern high production card is the most efficient machine producing about 70 lb an hour with 130 hp. The small alternative produces 2½ lb an hour and has the usual ½ hp motor;

(iii) Drawing: This process evens the sliver. As with the card, the modern drawframe with a production of about 135 lb an hour is more efficient than its predecessors. An alternative automatic model is used if it is desired to proceed to open end spinning omitting the moving stage. The small scale frame for use in hand spinning has the usual capacity of about 2½ lb an hour;

(iv) Roving: This further attenuates the sliver - about 7 draft. The latest model roving spindle runs at about 1300 rpm but a cheaper model at about 1000 rpm is also available. Hand-powered roving frames are used in hand spinning systems;

(v) Spinning: There are two main types of spinning: ring spinning and open end or break spinning. In ring spinning the roving is further attenuated by roller drafting to the fineness of the yarn required - usually a draft of about 20 - and at the same time twist is inserted to give the yarn the necessary strength. Full bobbins may be manually or automatically doffed. The maximum speed of the spindle is about 15,000 rpm. In open end spinning the sliver from the draw frame is broken into its constituent fibres within the spinning vessel (rotor) which revolves at about 50,000 rpm. Both systems may also be used in hand spinning but speeds are lower averaging about 4000 rpm end about 12,000 rpm respectively;

(vi) Cone winding: This facilitates subsequent processing by rewinding yarn on to a larger package and removing faults. Three alternative machines are available all running at about the same speed - 1000 to 1250 yards a minute - but differing widely in degree of autor ation from manu l to advanced (which feeds ring tubes and automatically pieces up breakages).

This stage is not necessary for hand spinning which does not benefit from rapid processing and it is not strictly necessary in open end spinning since the spun package is already large enough. Again if yarn can be spun on a small package which can be used directly in the weaving shuttle the rewinding of weft may be avoided;

(vii) Warping: This assembles the warp threads in a form suitable for sizing and drawing in to the loom. As indicated above the modern beaming machine is a high capacity one which can handle about 7000 yards an hour but is more efficient than its predecessors. For hand weaving a warping machine of about 15 yards an hour capacity can be obtained;

(viii) Slashing: At this point the yarn is sized to reduce breakages at the weaving stage. Capacity of the modern slasher is about 3500 yards an hour although a less efficient machine would be equally satisfactory if neither were fully employed. In hand weaving operations hand sizing is used;

(ix) Drawing in: The drawing in of the sized warp threads through the healds, reed and dropwires of the loom may be done either manually by a pair of workers drawing some 480 ends per hour or by one worker with a reaching in device or automatically at about 1200 ends per hour;

(x) Pirning: This comprises winding the yarn on to a package suitable for inserting in the shuttle of a loom. This stage is unnecessary for shuttleless looms or where direct spinning is possible. There is a choice between semi-automatic and automatic machines, the latter having automatic feed. The small-scale, hand-powered machine used for hand looms operates at about 80 yards a minute compared with 1000 yards for power winding; and

(xi) Weaving: The main choice is between shuttle looms and shuttleless looms. Shuttle looms range from hand looms to non-automatic power looms to automatic looms the progression being towards more automated, labour-saving, capital-intensive machines. Within the automatic loom class there are a number of alternative models varying in speed and ease of operation and there are also accessory labour-saving devices - such as box and unifil - available.

The shuttleless looms consist at present of three types, projectile (Sulzer)., rapier and air jet. They are all considerably faster than the automatics and cost more, resulting in considerably lower labour but somewhat higher capital requirements per unit of output.

A complete manufacturing profile involves one technology from each of the stages outlined above so that the total number of possible profiles runs into thousands.

(3) Economic Evaluation and Policy Conclusions

The large number of technological profiles just mentioned forms the set from which particular members may be drawn in the pursuit of particular industrial, economic and social objectives. To proceed, however, to such selection two (inter-related) things are required: additional, largely economic information; and a method of evaluating the alternative technologies. Moreover given what has earlier been said about the importance of the surplus, evaluation should initially at least be made to turn on profitability. Once alternative technologies have been thus evaluated it becomes possible to consider policy questions in an informed way. In the light of the foregoing it seems logical to organize this section of the paper in three parts - covering additional information, evaluation and policy conclusions respectively.

(i) Additional Information

In order to select the lowest cost technology it is necessary to know first the operating costs which include wages, materials and power and secondly the capital costs which include machines, buildings and working capital. These parameters vary from country to country so that the task of producing firm results for all developing countries would be a large one. As a first step to reducing this task, it may be suggested that specific country results would stand more regional than international generalization across regions; and, accepting this, to limit consideration to Africa.

Africa is in general a low wage region with a per capita GDP of less than one-third of that in Latin America. According to UN industrial statistics, earnings per head in the textile industry in 1974 ranged from US $400-US $500 in Kenya and Ethiopia to US $950-US $1050 in Ghana and Egypt. Comparable figures for India and Hong Kong are US $550 and US $2350 respectively. To lend even wider perspective to the African figures those for Mexico (US $3000), the UK (US $800) and the USA (US $7000) may be cited.

These limited statistics indicate that - as is well-known in any event - Africa is not a homogeneous region. In order, therefore to increase the specific content of the subsequent evaluation it is useful to take two African countries representative respectively of each of the two wage regimes identified above. These, in the light of the international range may be described as 'medium' and 'low' wage areas respectively.[1/] Selection on the basis of wage regime is justified - that is, made robustly usable - by the fact that, as shown in Table 3, there is a broad correlation between wage levels and productivity.

1/ For a fuller account of the operating conditions in the two countries see Pickett and Robson, "A Note on Operating Conditions and Technology in African Textile Production", *World Development*, Vol.5, Nos.9/10, 1977.

TABLE 3

Estimated Productivity Pattern in Two African Countries, 1976
(UK = 100)

		U.K.	Africa: medium wage country	Africa: low wage country
Average operative earnings in $ per hour		100	15	6.67
Output per unit:	spinning	100	90	85
	weaving	100	90	90
Units per operative:	spinning	100	36	16
	weaving	100	47	25
Output per operative:	spinning	100	32	14
	weaving	100	42	22
Annual wage cost:	spinning	100	47	47
	weaving	100	36	30

Two observations should be made on this table. First the units involved are ring spindles and automatic looms of modern design - about 1965 vintage and the staffing is compared with that obtaining in U.K. practice. Secondly even though the sample size is small there is some variation around the average. In particular one firm in three investigated in the medium wage country, with good management and air conditioning and located favourably in regard to labour was able to operate at UK levels of productivity.

An important characteristic of wage rates in African countries is that, as shown in Table 4, earnings of unskilled labour are relatively low and of skilled labour relatively high within the overall wage structure in comparison to a developed market economy such as the UK.

TABLE 4

Relative Wage Structures in Textile Production

	U.K.	Africa	
		medium wage country	low wage country
Unskilled: labourers etc.	80	65	60
Semi-skilled: machine tenders	100	100	100
Skilled: mechanics, clerks	125	150	160
Supervisory	150	200	200

More this phenomenon applies also to administrative salaries, partly because of the importance of expatriate management in Africa.

Turning now to capital costs, Africa is entirely dependent on imported machinery and it is estimated that freight and insurance adds about 10 per cent to f.o.b. prices where coastal locations are concerned and a higher percentage for interior locations. In addition installation costs will add a further 5 per cent.

Building costs which usually involve imported steel and other components are also relatively high - quotations of about $15 per sq. ft. for a good single storey steel structure were obtained in 1976. In addition electrical and plumbing equipment, air conditioning, boilerhouse and workshop can amount to more than the cost of the building or with the building about half the cost of the textile machinery installed. Working capital is important because of the need to keep adequate stocks of materials and spare parts - normally at about twice the levels maintained in developed countries.

It should be clear that the purpose of this discussion of the additional information required on African costs is not intended exhaustively to cover all operating and capital costs - although these are included in the evaluation of technologies. Rather it has concentrated on the more obvious costs and those most likely to influence technology choice.

It is also hoped that the discussion has implicitly brought out difficulties which have to be overcome in the design of a basic needs (or indeed any systematic) strategy of industrial development.

(ii) Evaluation of Profiles

To identify the lowest cost technology it is necessary to combine capital and operating costs and this involves a decision on the expected return on capital. It has become almost customary to use a discount rate of 10 per cent for this purpose; annual receipts and costs are discounted at 10 per cent over the life of the plant to give the Net Present Value (generally accepted as the appropriate measure of the surplus) and projects are approved which have a NPV greater than zero. This rate should be applied to real costs and real receipts but if it is assumed that either prices will be constant or that all will increase in step, then current prices may also be used for the selection of projects on a commercial basis. For most developing countries however it might be that 10 per cent is too low having regard to the shortage of capital and that only projects which pass at a 20 per cent rate should be accepted.

If alternative technologies result in a product selling at the same price then, since receipts are the same for all alternatives, it is sufficient to calculate the present value of costs (PVC).2/

For a discount rate of 10 per cent and a life of 20 years it can be shown that by using the discount method allowance is in fact being made for an 11.75 per cent gross return on capital.

2/ If it is assumed that operating costs are constant from year to year to year the required expression reduces to the simple form

$$P.V.C. = C + \frac{c}{r}\left(1 - \frac{1}{(1+r)^n}\right)$$

where C is the initial capital investment, c the annual operating cost, r the rate of discount and n the life of the plant in years.

There is an obvious difficulty when the life of the various assets is different. The only example of practical importance, however, is the life of the building which will normally greatly exceed that of the machines installed. If the building has a life of 40 years then for an on-going enterprise it would not be necessary to invest in another building when re-equipping, so that if B is the initial cost of the building its value at the end of twenty years discounted to present values is $B/(1.1)^{20}$ or .17.B.

Another difficulty is that the output of the various technologies is not the same. There are two main reasons for this, the first and most obvious being that of scale of manufacture. As noted above power operations will only use fully the capacity of all machines at a level of about 700 looms, while hand loom operations can be carried out on a very small scale.

The second reason is more technical. Spinning on the open end principle saves about 2 per cent of raw cotton for the same output of yarn or alternatively gives 2 per cent higher output for the same cotton consumption. Again, shuttleless looms need up to 6 per cent more yarn than shuttle looms because of the extra requirement of weft in forming a selvedge. These difficulties are met by expressing costs on the basis of the same output per annum which, ignoring for the moment any constraints arising from the size of the market, means in practice that for power production an annual output sufficient to use capacity at all stages - about 28 million yards of 40" cloth per annum - is taken.

As already noted the major interest in this paper is in the relation between technology, costs and employment. This may be comprehensively illuminated by considering four of the many possible alternatives: hand spinning and weaving; and three types of power spinning and weaving - namely production on non-automatic looms and ring spindles, on automatic looms and ring spinning and on Sulzer looms and open-end spinning. Some relevant figures are provided in Table 5 below for a low wage African country. Capital cost and operating costs are grouped into four sections, spinning, preparation, weaving and administration. It will be noted that where technologies are

TABLE 5

Capital and Annual Operating Costs (at 1976 prices) and Manning Requirements for the Production of 28 Million Square Yards of Cotton Cloth per Annum in a Low-Wage African Country
(in US $'000s and numbers)

Stage:	Technology: Open-end spinning & Sulzer weaving 3-width	Ring Spinning & automatic weaving 3-width	Ring Spinning & automatic weaving 1-width	Ring spinning & ordinary looms
1. Up to and including spinning				
Capital:				
machinery	$4949	3471	3428	3428
buildings	$ 604	671	663	663
working	$ 179	205	203	203
Operating costs:				
labour	$ 136.0	229.2	226.3	226.3
power	$ 172.5	160.8	158.8	158.8
maintenance	$ 178.5	205.3	202.7	202.7
cotton	$7740.8	7893.4	7795.2	7795.2
Employment	247	547	540	540
2. Preparation:				
Capital:				
machinery	$1140	1361	1344	1344
buildings	$ 320	322	318	318
Operating costs:				
labour	$ 124.8	142.9	141.1	141.1
power	$ 0.5	0.5	0.5	0.5
maintenance	$ 43.8	52.7	52.0	52.0
Employment	234	276	273	273

Table 5 (cont/d.)

Stage:	Open-end spinning & Sulzer weaving 3-width	Ring spinning & automatic weaving 3-width	Ring spinning & automatic weaving 1-width	Ring spinning & ordinary looms
3. Weaving:				
Capital:				
machinery	$7600	3056	3978	733
buildings	$ 620	1096	1015	1075
working	$3040	3064	3065	2850
Operating costs:				
labour	$ 141.2	422.6	567.0	1031.2
power	$ 63.1	111.6	157.9	66.9
maintenance	$ 253.5	223.5	259.1	44.0
Employment	264	801	1119	1896
4. Administration:				
Buildings:	$3000	3000	3000	3000
labour	$ 650	650	650	650
utilities	$ 246	246	246	246
materials	$ 120	120	120	120
Employment	500	500	500	500
5. Total:				
Capital:				
machinery	13689	7888	8750	5505
buildings	4544	5089	4996	5056
working	3219	3269	3268	3053
Operating costs:				
labour	1052.0	1444.7	1584.4	2048.6
power	482.1	518.9	563.2	472.2
materials	7860.8	8013.4	7915.2	7915.2
maintenance	475.9	481.5	513.8	298.7
Employment	1245	2274	2432	3209

the same the minor differences in cost are a result of levelling up to the same output.

At the spinning stage the capital cost of open end spinning is some US $1.5 million higher than ring spinning but saves some US $0.2 million on annual costs. Combining capital and operating costs at 10 per cent discount PVC for open end spinning comes to $75.75 million and for ring spinning $75.63 - a negligible difference and in part due to lower cotton consumption which should be offset to some extent by sales of waste. At 20 per cent cent discount however the gap widens with the relevant figures being US $45.8 for open end and US $45.1 million for ring spinning.[3/]

At the weaving stage there are much greater differences in investment, the capital cost of Sulzer equipment being about twice that of automatic looms and about ten times that of non-automatic, but differences in operating costs are lower. Discounting at 10 per cent PVC is lowest for 3-width automatic weaving at US $13.66 million and then in order non-automatic at US $14.37 million, Sulzer US $15.16 million and last single-width automatic weaving at US $16.43 million. At a 20 per cent discount rate non-automatic looms become the cheapest.

At the preparation stage shuttleless looms (Sulzer) gain slightly because no pirning is necessary.

In the light of the concerns of this paper it is necessary to focus across technology on investment costs, profitability and employment. This is done for the three 'modern' technologies in Table 6.

3/ Sales of waste are neglected.

TABLE 6

Profitability (PVC), Investment and Employment (at 1976 prices) for Three Technologies in a Low-Wage African Country

	Open end spinning & Sulzer weaving (A)	Ring spinning & automatic weaving: 3-width (B)	Ring spinning & automatic weaving: 4-width (C)	Ring spinning & ordinary looms (D)
PVC:				
@ 10 per cent	US$105.45m.	US$105.25m.	US$107.02m.	US$104.97m.
20 per cent	US$ 69.52m.	US$ 67.18m.	US$ 68.52m.	US$ 65.89m.
Employment	1245	2274	2432	3209
Capital	US$ 21.45m.	US$16.25m.	US$ 17.01m.	US$ 13.61m.

The differences in PVC are small, but the differences in employment are large and those in investment costs not negligible. At both discount rates the ring spinning/ordinary loom technology would be the economically efficient choice. It would also have the lowest investment cost and provide the most employment. At the medium wage level, the weaving wage cost would be increased by 20 per cent. This would be sufficient to make Sulzer weaving the lowest cost, the PVC figures in the above order being: US$105.89 million, US$106.21 million, US$108.21 million, US$106.62 million. The association between wage levels and productivity would affect capital costs and employment, but not sufficiently to invalidate the first sentence of this paragraph.

The advantage of non-automatic weaving depends on the skill of the operatives and although the rates taken for a low wage area are representative namely 9 looms a weaver for automatic looms and 2 for ordinary looms there is more risk of output falling below target in ordinary loom weaving both in quantity and quality. On the other hand administrative charges might easily be lower than taken above since a simple factory building and no air conditioning might be expedient.

Turning now to the effect of scale of operation on the profitability of the various technologies, if the scale of operation were doubled nothing much would happen in regard to costs. Probably the only saving would be at the warping stage which would then be fully occupied. Moving, however, to progressively lower levels of output leads to significant changes. These come partly from administration where broadly a reduction in scale of operation by one half will reduce administrative costs by only one quarter - so that administrative costs per unit will rise by one half. Secondly the technical factor becomes steadily more important. As soon as output falls below 28 million square yards per annum the opening line can no longer work to capacity on three shifts and this is soon also true for warping and slashing equipment. To varying degrees this may be offset for a time by using less productive techniques, thus it may be possible to get cheaper although less efficient machines at the warping and sizing stages and at the drawing in stage automatic processes can be replaced first by reaching in mechanisms and eventually by hand methods. Because of the low capacity of individual spindles and looms these processes are only affected at very low scales of output. Below 50 looms or so, however, staffing becomes difficult and eventually shift working would have to be abandoned. Assuming that labour can be deployed throughout so that an hour's work results in an hour's pay the position at this low level of output i.e. about 1¼ million yards per annum is shown for ordinary looms, together with that for the 'standard' level of output, in Table 7.

TABLE 7

Annual production on ordinary looms at two different levels of output in a low-wage African country

	28.1 million square yards				1¾ million square yards			
	capital cost	operating cost	P.V.C. per square yard	Employment per million square yards	capital cost	operating cost	P.V.C. per square yard	Employment per million square yards
	US$000	US$000	US$		US$000	US$000	US$	
Up to & incl. spinning	4294	8383	2.69	19.2	711	541	3.03	19.8
preparation	1662	194	0.12	9.7	126	22	0.18	17.8
weaving	4658	1142	0.51	67.5	291	71	0.51	67.5
administration	3000	1016	0.41	17.8	950	230	1.66	90.0
All Stages	13,614	10,735	3.73	114.2	2,078	864	5.38	195.1

More use will be made of the data of Table 7 below. Here it suffices to note that moving to the smaller scale increases the PVC per yard by 44 per cent - largely because of the cost increases in the first and last of the four stages covered in the table.

Below the level of output just discussed capital costs would be unchanged and labour would be deployed on a single shift basis. The PVC of US $5.38 per yard would then rise for an output of about 600 thousand square yards per annum to US $6.67.

For a small hand spinning-hand weaving operation of 26 hand looms and either 230 mechanized or 104 open end spindles the annual output at 30 picks per minute is 78,000 square yards and relevant additional information is given in Table 8.

TABLE 8

Characteristics of Hand Spinning and Weaving:
Output 78 000 yds. per annum

	Capital	Operating	PVC per square	Employment per million yds.
	......$000........			
Up to spinning	7.2-8.9	75-80	11.4	1330
Weaving & preparation:	5.4			
working capital	17.2		3.3	370
Administration		4.3	0.5	38
	37.0-38.7	108.3-113.3	15.2	1738

Costs would, as can be seen, be about US $15 per square yard, compared with US $6.7 on ordinary power looms and ring spinning. This assumes, of course, that an operative commands, in effect, an hourly rate which is such that his or her annual income is the same as that earned by an operative in a modern mill. It would not be unreasonable in rural areas to assume half this wage; so that hand operations would be competitive with ordinary looms at or below half a million square yards a year. Employment would be much higher a 1738 per million square yards compared with 195 on power looms.

One way in which account is often taken of employment is to calculate social rather than market costs which in practice with the usual over-valuation of the currency, low saving rates and high differentials between rural and urban earnings means taking social wage costs at about half the actual cost. If this is done, then the hand operations become more attractive than before and in power operations labour-intensive technologies are generally favoured.

(iii) Policy Conclusions

In the opening pages of this paper emphasis has been placed on the generation of an economic surplus from productive activities in developing countries. In particularly happy circumstances there would be no conflict between this and the pursuit of other objectives - such as those frequently implied by the basic needs approach to development. That a single-minded approach to industrial development would serve a number of policy objectives equally well, however, perhaps unlikely. A multi-purpose programme is consequently likely to entail compromise, and the challenge to policy is to obtain the best compromise possible. This formulation leaves open some difficult questions as to what might constitute the 'best' compromise. Partly from conviction and partly to avoid long and inconclusive discussion, particular weight here is attached to minimizing the sacrifice of economic efficiency.

Other views on this matter are possible, and readers are reasonably free to impose their own, alternative criteria on the argument. It should, however, be recognized that economic efficiency and economic inefficiency are real phenomena, so that in some circumstances a policy, for example, of maximizing employment at any cost would not be objectively sustainable. This said, another point to be recorded is that the data and conclusions of this paper are necessarily tentative. As a consequence, as much importance is attached to the methods it uses as to the results it presents.

These qualifications and clarifications made, it is convenient in fairly dogmatic fashion to consider the policy options open to African countries in the development of a textile industry. One way in which this can graphically be done is to suppose that the countries listed in Table 1 expect their domestic markets to double in the next decade or so and wish to make provision for this on the further assumption that the expansion of demand will entirely take the form of cotton cloth. To facilitate the discussion it is useful to assume that the net present value of the optimal technology is such as to yield a margin of 10 per cent on costs.

On these assumptions, it may first be noticed that all but three of the African countries in question would need at least one integrated mill of a size capable of exploiting existing technical economies of scale. This being so, it is appropriate to proceed by considering alternative ways of satisfying this unit of demand;[4/] and to consider first the case where the demand is to be met by the setting up of a factory capable of producing 28 million square yards of cotton cloth per annum. Considering then the four technologies covered by Table 6 the position in a low-wage country, using a 10 per cent rate of discount would be as shown in Table 9. From this it can be seen that the optimal technology has the desirable properties of being the most

TABLE 9

NPV, Employment and Investment Costs (at 1976 prices) for Four Technologies in a Low-Wage African Country

	Technology A	Technology B	Technology C	Technology D
NPV	US$10 million	US$10 million	US$8.5 million	US$10.5 mill.
Investment	US$21.45 mill.	US$16.25 mill.	US$17.0 mill.	US$13.61 mill.
Employment	1245	2274	2432	3209

profitable *and* the most employment generating and least demanding of investible funds. As has been seen, this result is not sensitive to a doubling of the discount rate. It is, however, sensitive to changes in the wage rate and in a medium-wage country, the NPVs for Technologies A, B, C and D would be US$ 9.5 million, US$ 9.0 million, US$ 7.5 million and US $9.0 million, so that the most capital-intensive, least employment-generating technology would be the most profitable one. The sacrifice in economic efficiency involved in staying with the most labour-intensive, lowest capital cost technology would not, however, be inordinately great - amounting to about 5 per cent of optimal profits creating additional employment. These

4/ In countries where more than one 'optimal' mill would be required, it is assumed that, whatever solution arrived at, it would hold for the relevant number of units. It will be obvious that the argument is not based on any fine analysis of potential market (segments) and that it ignores variations in transport and distribution costs which would result from different forms of industrial structure.

may be expressed in a number of logically identical ways - an addition to investment costs, a decrease in NPV, an addition to PVC - and each of these can be expressed absolutely or per additional job created. Table 10 shows, for a low-wage African economy and a 10 per cent discount rate, the cost of creating extra employment in 16 'modern' factories, as described above, 47 factories each producing about 600 thousand square yards of cloth per year and the hand spinning and weaving question producing about 78 thousand square yards per annum. It would take 360 such units to produce the required amount of cloth, and these, it will be recalled, can defensibly be evaluated at two different wage levels. For simplicitly, and in the light of earlier, recurrent emphasis on profitability, attention is confined to NPV.

TABLE 10

The Cost of Creating Additional Employment by Alternative Technologies

	16 Factories	47 Factories	360 Factories 'High' Wage	360 Factories 'Low' Wage
Loss of NPV	US$46.5 mill.	US$72.12 mill.	US$311.8 mill	US$72.12 mill.
No. of jobs created	2273	-303	45,629	45,629
Loss of NPV per job	US$20,457.5	-	US$6833	US$1580

Putting this differently, for a lower initial investment outlay and a doubling of employment compared to that generated by the optimal one it would be possible to earn 95 per cent of the optimal profits.

It should be recalled that each of the four technologies just considered are capable of exploiting technical economies of scale. If, however, it were thought desirable to meet the project demand by means of smaller factories then no technology could reap these benefits, so that some trade-off between profitability and other objectives must be expected. Here the magnitude of such trade-off would be critical. In the present context this may be examined by combining the above assumptions with the data of Table 9 and thus, in effect, comparing the single large factory just discussed with 16 smaller factories capable of producing the same aggregate output. Confining attention, for convenience of exposition, to the ordinary loom (i.e. the optimal choice of Table 6), data relevant to the contrast are present in Table 11. From this it can be seen that the trade-off between employment and profitability cannot be accommodated

TABLE 11

Some Characteristics of Single and Multiple Factory Production of 28 Million Square Yards of Cotton Cloth per Annum in a Low-Wage African Country

	Single Factory	16 Factories
NPV	US$10.5 million	-US$36.0 million
Investment	US$13.61 million	US$33.4 million
Employment	3209	5482

within the surplus indicated in the table, so that a decision to choose the 16 factories rather than a single mill would go beyond the sacrifice of positive profits into actual subsidy.

This is a disappointing result, the more so since it evidently applies *a fortiori* to the smaller-scale and hand looms operations discussed above. It is consequently important to stress that it is sensitive to some extent to changes in the particular parameters used in the present calculations. The result is, nevertheless, plausible - particularly in the light of recent technical progress; and perhaps the most useful policy implication of the paper is consequently that of highlighting the need to determine systematically, and on an industry-by-industry basis, where there are and where there are not 'sensible' opportunities for decentralized, small-scale production.

In this regard, the present results can be used as a frame on which to hang some further illustrative discussion. The first point to be made is that any disappointment felt about the apparent economic undesirability of the smaller-scale production should clearly be tempered by the results of the evaluation of the large-scale alternatives - which, as has been seen, suggest that the choice of the most labour-intensive technology is an attractive policy option. Indeed, even in medium-wage countries some 95 per cent of maximum surplus could be obtained if this choice were made, with an increase in employment of almost 160 per cent over that associated with the optimal technology - at a once-and-for-all cost of US$255 per extra job.

The employment gains from small-scale production would, of course, be very much greater than those resulting from a labour-intensive, large-scale technology. It is, therefore, worth probing further the costs of such production, although to do this fully would require much more macro- and micro-economic data than is presently available. One thing which can, however, be said is that the scope for - or at least the desirability of - modifying choice in a small-scale direction depends greatly on the prices at which alternatives are evaluated. If the results presented above were based on shadow prices which accurately represented agreed development goals, then any move from the optimal technology would result in a distortion of resource allocation and there really would be little more to be said. If, however, the prices were those thrown up by an imperfect market economy in which, for example, incomes were very unequally distributed the situation could be very different - although it bears emphasizing that, rigorously speaking, it would remain complex.

It is worth considering briefly if rather impressionistically what policy options might be adopted (and at what cost) in such an economy. This may usefully be done by first considering costs, which are essentially those of providing additional employment beyond that associated with the optimal technology.

The first impression from the table is that, in the circumstances assumed, job creation would be expensive in that the loss of NPV associated with, 16, 47 and 360 factories could finance between 3 and 24 factories each capable of producing 28 million square yards of cloth per annum. If, nevertheless, it were felt that - perhaps to avoid undue concentration of industry in urban areas and increase the spread and number of jobs - the single factory option should be ruled out, then (provided the absolute cost is not an insuperable barrier) Table 10 suggests that the hand operations would be preferable to small-scale variants of power technology. Here two things may be noted. The first is that the cost (loss of NPV) per job in the 16 factory option is considerably higher than the discounted value of the annual wage per operator, so that in principle it would be profitable to pay the additional workers the normal wage to stay away. In practice there could be very serious administrative and political difficulties associated with this method of subsidizing unemployment. The second thing to note is that whereas the 47 factory option - because of the move to single shift working - actually reduces employment, hand operations very significantly increase it at a cost per job which is considerably lower than the discounted wage. Indeed a once-and-for-all expenditure of US$1580 per job does not at first blush seem excessive. When, however, it is recalled that this is 15 times the GDP per head in many countries, it is clear that a subsidy of this magnitude could not be provided across the economy.

Another way of looking at the matter can be introduced by asking how the necessary subsidy would be raised. One possibility clearly would be to tax the consumers. The present assumptions imply a selling price of cloth of US$4.10 per square yard. To enable the hand operators (at the high wage rate) to break even this would have to be increased by more than 70 per cent. The increase need not fall on the cloth directly, but could be levied on the final product made from the cloth. This would have several advantages. In particular it would permit a discriminating impost to be made on products according to income levels (as expressed in demand) and give no incentive for an illicit trade to develop in cotton cloth.

In the present state of knowledge and in a brief paper a number of important matters have either been ignored or drastically oversimplified. In many countries - notably in India - modern and traditional sectors already co-exist, so that an explicit discussion of a 'mixed' development might have been desirable. The present discussion has, however, offered some guidance (hints) on how the relations between these two sectors might be organized. It has, moreover, given some insight into the reasons why in India the survival of the traditional sector could not be left to the market.

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