THE PATTERN OF TECHNICAL PROGRESS IN THE ETHIOPIAN MANUFACTURING SECTOR

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Abstract

Cognisant of the fact that the pattern of technical progress being capital saving or labour saving has an implication in formulating industrial policy environment to fine-tune the direction of the dynamic comparative advantage of any country, examining the pattern of technical progress in the Ethiopian Manufacturing sector becomes relevant. To this end, this paper attempts to identify the pattern of technical progress using different econometric models.

The result has come out to show that the production technology in the Ethiopian manufacturing sector is capital consuming and labour saving contrary to the theory of initial factor endowments of the country. This result indicates that technological choice was inappropriate and technological capability acquisition was not built-in in the Ethiopian manufacturing enterprises.

This result reminds us that, for Ethiopia to industrialise, firms have to build the necessary technological capabilities through experiencing in production and investing in learning. Firms have to put a deliberate effort to adapt and improve technology to the Ethiopian prevailing conditions This result reminds us as well that the government, in order for firms to develop their technological capabilities, has to install a favourable enabling environment, develop a mechanism protecting selected manufacturing enterprises, investigate ways to promote technological efforts of manufacturing enterprises and design ways to subsidise firm-level research and development.

1. INTRODUCTION

Neither the static Hecksher-Ohlin theory nor product cycle theories are sufficient to explain the evolution of comparative advantage. In this sense, least developing countries like Ethiopia are neither prisoners of initial factor endowments nor mere imitators of earlier industrialised countries (Herbert-Copley 1990:1464). There is room for manoeuvring their own destiny. Initial factor endowments or the current comparative advantage of any country can be changed, given the fact that sufficient consideration is accorded to technological capability acquisition. Technology here should be understood as defined by Fransman (1984:9-10) that encompasses every thing pertaining to the transformation of inputs into outputs which include social organisation of the production and labour process, knowledge and competition. Any change in these will bring technological change since they have a bearing on the transformation of inputs into outputs. Technological capability acquisition implies building up the capacity to search for and select technologies for use in particular environments; operate, assimilate, adapt and modify processes and products in the light of the prevailing conditions in Ethiopia.

The rate, pace and direction of technical progress (all the traits and activities of acquiring technological capability) achieved in any particular country could alter factor endowments and hence the dynamic comparative advantage of that country. But the rate, pace and direction should be in the right direction.

Especially, the nature of technical progress whether it is labour saving or capital saving is an indication of the technological capability acquisition efforts, more particularly of the effort of technology selection and adaptation of a particular country. This, as well, has an implication in formulating industrial policy environments to fine-tune the direction and movement of the dynamic comparative advantage of the country. The main theme of the paper is to look into these issues and to contribute/produce empirical evidences in the area, which are scant and patchy regarding the Ethiopian manufacturing sector.

The objective of the paper, therefore, is identifying the nature of technical progress in the Ethiopian manufacturing industries, whether it is labour saving or capital saving.

2. TECHNICAL PROGRESS: CONCEPT AND MEASUREMENT

2.1. Concept

There does not seem to be a consensus among scholars on the concept of technical progress. That is why Kennedy and Thirlwall (1972:12) said, "over the years the term technical progress has been given a range of meanings and interpretations".

However, there is a convergence of thought among scholars in one respect. At least, all understand that it is an addition/advance in technological knowledge, which has a bearing on production. Technical progress includes all forces which raise the combined productivity of all factors of production. It is a shift in the production possibility frontier over time that enables all concerned to produce greater output with the same volume of inputs. It is a move towards the best-practised production possibility frontier through learning.

Technical Progress has two potential sources: technical change and technological progress. Technical change refers to a change and/or an alteration of the choice of techniques out of the existing art. It is the acquisition of knowledge through experience in production (the process of learning-by-doing). Jackson (1982: 339) describes this as follows:

> ... as the work force becomes accustomed to, and experienced in, the production process, the workers steadily learn how to do tasks more efficiently and quickly. At the beginning, nothing is routine, everything is unfamiliar, and it takes time to learn how to cope with snags. After time, everything is routine and familiar, and the quickest and best way of dealing with snags and awkward parts is well known.

Technological progress implies an expansion in the shelf of international technology and an addition to the stock of technological knowledge. The following matrix can summarise technological advance.

Table 1: Technological Advance Matrix

Products/Services	Methods of Production		
	Existing Method	Improved Method	New Method
Existing Products/Services	1	4	7
Improved Products/Services	2	5	8
New Products/Services	3	6	9

Source: Jackson: 1982: 316.

Position 1 in the matrix is the present state of production technology and any shift/movement from 1 to any one of the eight positions purports technological changes.

Here, it shall be noted that introduction of unused but known technique or its diffusion is not a technological change. In practice, however, "it is extremely difficult to distinguish improvements in efficiency due to movements towards known production boundaries from the expansion of the boundaries themselves due to increases in knowledge" (Kennedy and Thirlwall 1972:12).

But communication gap or level of capability would keep a good part of the world technology shelf in the dark. Then, the diffusion of hitherto unused but known (or existing) techniques somewhere could be considered as technical progress in countries like Ethiopia.

Technical progress is also different from increasing returns to scale, as the former does not necessarily require addition of scale.

2.2. Measurement

There does not exist an easy direct measure of technical progress. Kennedy and Thirlwaill stated that "advance in knowledge per se defies direct meaningful quantification. The best that can be done is to measure technical change by its effects, such as its impact on the growth of total productivity..." (Kennedy and Thirlwall 1972:13).

The impact of technical progress on output growth can be estimated using a general production function of the form:

$$Q = F[L(t), K(t), t] \ldots\ldots\ldots \quad [1]$$

where t is time. The change in output overtime is given by

$$\frac{dQ}{dt} = \frac{\partial F}{\partial L}\frac{dL}{dt} + \frac{\partial F}{\partial K}\frac{dk}{dt} + \frac{\partial F}{\partial t} \ldots\ldots \quad [2]$$

The change in output is decomposed into two: Change in output due to a movement along the production function and the change in output due to a shift in the production function or due to disembodied technical progress (see Intriligator 1978:289). Dividing Equation [2] by Q and converting to proportionate change yields:

$$\frac{1}{Q}\frac{dQ}{dt} = \frac{L}{Q}\frac{\partial F}{\partial L}\frac{1}{L}\frac{dL}{dt} + \frac{K}{Q}\frac{\partial F}{\partial K}\frac{1}{K}\frac{dk}{dt} + \frac{1}{Q}\frac{\partial F}{\partial t} \ldots\ldots \quad [3]$$

The first two terms on the right are the proportionate rate of change of the two inputs, each weighted by their respective elasticity of output. The third term is the proportionate rate of disembodied technical progress. Assuming that the elasticity remains fairly constant overtime and the proportionate rate of disembodied technical progress is constant at a rate m, Equation [3] can be converted into the following:

$$\frac{1}{Q}\frac{dQ}{dt} = a\frac{1}{L}\frac{dL}{dt} + b\frac{1}{K}\frac{dk}{dt} + m \ldots\ldots\ldots \quad [4]$$

where a and b are the labour and capital elasticity of output respectively. Solving for m and assuming dt=1, Equation [8] turns out to be:

$$m = \frac{dQ}{Q} - a\frac{dL}{L} - b\frac{dk}{K} \text{........} \qquad [5]$$

Rate of technical progress is thus the difference of output change from the combined input change; inputs are combined weighted by their respective elasticity of output. The above result is implied by a Cobb-Douglas production function of the following:

$$Q = A_o e^{mt} L^a K^b \text{........} \qquad [6]$$

where Q= output, L= labour input, K= capital input, m= proportionate change of Hick's neutral disembodied technical progress, A_o = initial efficiency parameter, t= time and a and b are partial elasticity of output with respect to L and K respectively (a and b are non-negative)[1].

If Cobb-Douglas technology does not characterise the production process, other functional forms such as Constant Elasticity Substitution (CES) technology or Translog technology could be used and one would reach at the same result. It requires only transforming the efficiency parameter as an increasing function of time. In this case, technical progress can be introduced in the CES technology as follows:

$$Q = \gamma_o e^{mt} [\delta K^{-\rho} + (1-\delta) L^{-\rho}]^{-\frac{v}{\rho}} \text{......} \qquad [7]$$

In the Translog technology, it will take the form:

$$LnQ = Ln\gamma_0 + mt + \alpha_1 LnL + \beta_1 LnK + \alpha_2 (LnL)^2 + \beta_2 (LnK)^2 + \gamma_1 LnLLnK \qquad [8]$$

m represents Hicks neutral disembodied technical progress.

Other than the different types of production functions, there are different alternative methods of measuring technical change such as profit/cost functions, divisia index or the Tornqvist index. The latter two indices even do not involve or require an econometric estimation of production, cost or profit functions.

3. NATURE OF TECHNICAL PROGRESS

Technical progress has various prefixes: Exogenous, endogenous, disembodied, embodied, neutral, labour saving, or capital saving depending on its impact on factor productivity and its sources and carriers. Embodiment is an issue of vintage as a carrier of technological progress, giving different weights to different vintage of technology

Neutrality is an issue of whether technical progress causes an equi-proportionate rise of factor inputs' efficiency. There are Hicks neutrality, Harrod neutrality or Solow neutrality; their difference is on whether technological progress leaves factor ratios unchanged (Hicks), capital-output ratio unchanged (Harrod), labour-output ratio unchanged (Solow) for given factor prices (Heathfield and Wibe 1987:121).

3.1. Non-Neutral Technical Progress

There is a method for identifying whether technical progress is neutral or not. One simple method is to measure factor inputs in their efficiency units (Heathfield and Wibe 1987:123). As time passes, each man-hour gets experience and becomes more efficient. As well, capital input especially through replacement investment embodies new technology, which is more efficient. Factor inputs in production should, as a result, be measured in their efficiency in order to identify whether technical progress is capital or labour saving. This requires a general Cobb-Douglas production function of the form

$$Q = A\,[L(t)]^{a}\,[K(t)]^{b} \ldots \qquad [9]$$

where K(t) and L(t) represent capital and labour inputs in their efficiency units. The basic assumption here is that as time passes, their efficiency increases. To make it specific, let

$$K(t) = e^{nt}K_e \ldots \qquad [10]$$

and

$$L(t) = e^{vt}L_e \ldots \qquad [11]$$

where K_e = actual capital input, K= capital input in efficiency unit, L_e = actual labour input, L = labour input in efficiency units, n and v are rates of growth of efficiency per unit of time.

Through substitution, Equation [9] turns out to be:

$$Q_t = Ae^{avt}e^{bnt}L_e^a K_e^b \ldots \qquad [12]$$

or

$$Q_t = Ae^{(av+bn)t}L_e^a K_e^b \ldots \qquad [13]$$

If n = v, technical progress is Hicks neutral; it raises efficiency of factor inputs at the same proportion. If n = 0, it is Harrod neutral and technical progress is labour saving;

and if v = 0, it is Solow neutral implying that technical progress is capital saving. If there is a need to use CES or Translog technology, the mechanism will be the same - use factor inputs in their efficiency unit. This method of estimation is not employed in this paper for lack of easy estimation techniques.

Another method is that of Katz. Katz (1969:97-99) used CES technology of the following form:

$$Y = [(E_L L)^{-\rho} + (E_K K)^{-\rho}]^{-\frac{1}{\rho}} \ldots \quad [14]$$

where $E_L K$, and $E_K K$ constitute, respectively, the inputs of labour and capital in "efficiency units"; L and K being conventional measures of such inputs. It assumes constant returns to scale. Changes in E_L and E_K through time are considered as "labour-augmenting" and "capital-augmenting", respectively. Assuming efficient input use in production and the relative efficiency of labour take place at a constant geometric rate, they arrived at a regression model in logarithmic form, which can be written as follows[2]:

$$\text{Log}\frac{K}{L} = A_o + \frac{\sigma}{(1+\sigma)}\text{Log}\,\pi + (\varepsilon_L - \varepsilon_K)t \ldots \quad [15]$$

Equation [15] can be fitted by OLS to aggregate data on capital, labour and relative factor shares for the manufacturing sector to identify whether technical progress is non-neutral and whether it is biased to labour or to capital. Katz (1969:108) employed this method on the Argentine manufacturing sector and found out that it was labour saving: the efficiency of labour grew at a rate which was 1.6 to 1.7% higher than the rate at which the efficiency of capital grew through time.

Another method, which does not limit the extent of substitution or returns to scale, is the augmented Translog production function. Treating time as the variable that captures technical progress, Translog technology of the following form can be used

$$lnY = lnA_o + a_1 t + a_2 t^2 + \Sigma b_i LnX_i + 0.5\Sigma\Sigma b_{ij}\,\text{Ln}\,X_i\,\text{Ln}\,Y_j + c_i t\, lnX_i + u \ldots [16]$$

where Y= output, t= time, x= inputs (labour and capital) **and** $b_{ij} = b_{ji}$. This specification allows the calculation of the rate of technical progress,

$$\frac{\partial lnY}{\partial t} = a_1 + 2a_2 t + \Sigma c_i lnX_i \ldots \quad [17]$$

which incorporates both the effect of disembodied technical progress (a_1 and a_2) and the effect of any bias in technical change on the use of each of the factor inputs (c_i).

The c_i coefficient indicates the extent to which technical change is biased towards the particular factor input. That is, technical progress is factor i using, i-neutral or i saving if the estimate of c_i is positive, zero or negative, respectively. Both the latter two approaches are utilised in this paper using aggregate and longitudinal data.

3.2. Embodied Technical Progress

Embodiment is an issue of whether the recent capital and labour inputs acquire the latest technology and better quality. In this regard, Hildebrand and Liu (1965:49-52) tried to devise some proxy or dummy variables that would reflect changing technology to a significant extent. They assumed that important change in the level of technology could not take place without being reflected in the following:

- a change in the ratio of the value of equipment to the value of plant;
- a change in the average age of the capital assets as expressed in the ratio of the net value of assets to the gross value; and
- a change in the ratio of technical and professional personnel to production workers.

They proposed a Cobb-Douglas production function, which enables to incorporate technology explicitly as a variable of the following type:

$$Q = AL^{(a \log r)} K^{(b \log R)} \ldots \qquad [18]$$

where r = the ratio of technical personnel to production workers and R= the ratio of equipment to plant or the ratio of net value to gross value of capital assets. In this setting, factor-output elasticity or factor ratios will not remain constant overtime since the exponents are (a log r) and (b log R).

For a given level of technology, r and R are constants, and therefore the exponents are also constant. In this case, changes in quantities of labour and capital inputs would result in changes in output along a given production surface (Hildebrand & liu, 1965:50). Shifts in production would take place as the exponents themselves change when the technological level (or the level of mastering and adapting technology and learning-by-doing) itself undergoes changes, modifying the original surface. The exponents will change only if r and R changes; and they would only change, in normal cases, if there were a change in the level of technology itself or in the use of technology.

Solow and Intriligator (Intriligator 1978:291) had estimated embodied technical progress using vintage model. Intriligator estimated a production function incorporating both embodied and disembodied technical progress for aggregate US manufacturing output for the period 1929-1958. According to this estimate, disembodied technical progress was 1.67 percent per annum and technical progress embodied in capital amounts to on average 4 percent annually (Intriligator, 1978:292). Hildebrand and Liu (1965:58-62), using Equation [37], tried to incorporate technological change in the production function and attempted to identify the capital-output elasticity and technology-output elasticity for the three digit industries of USA; and their result had come out to indicate that technical progress was, by and large, capital embodied.

To identify whether or not technical progress is embodied in labour or capital, Equation [18] is employed in this paper; r, which is taken to be the ratio of labour cost of non-production workers to production workers in per cent, and R are used as proxy measures to capture technological change.

Payment to non-production workers is assumed to represent payment to technical and professional personnel, which have more relation with the extent of technology utilisation than production (or manual) workers. The problem here is that payment to non-production workers might not be a good representation of technical and professional personnel. It would have an upward bias as the former includes other payments. Furthermore, payment to production workers heavily correlates with the extent of capacity utilisation. If capacity utilisation falls for whatever reason, there will be a tendency to reduce, at least, temporary manual workers.

R is the ratio of the value of equipment (machinery, tools, etc.,) and the value of the plant (structures, buildings, etc.,), which indicates the extent of "technological intensity". The problem here is the way the plant and equipment are assumed to depreciate. The rate at which equipment are assumed to depreciate is quicker than that of the plant which leads R to vary without any implication on technology. Had it not been for lack of data on gross fixed asset, the "average age" of the capital assets would be preferable.

3.3. Data: Source and Measurement

Measuring technical progress has not only conceptual but also measurement problems especially on measuring output and factor inputs. Which output (gross or net), labour (man-year or man-hour), and capital (net or gross) reasonably reflect the productive content of inputs?

Net or gross output: Due to its heterogeneous nature and difficulty of aggregation, measuring output physically is hardly possible even at an enterprise level. Furthermore, physical output as a measure of 'production' does not take account of difference between the quality of the two products; nor does it take into account the work done to achieve the improvement in quality (Silver 1984:38). Thus, it becomes customary to focus on value measures; the issue again is which value to use - gross or net?

To measure technical progress properly, output should avoid double counting if figures are to be aggregated and should include additional works done on intermediate inputs while excluding works done by others. Output, which excludes brought-in materials, double counting and includes additional works is then net output (value-added).

In this paper, output will, therefore, be measured by value-added in national account concept at factor cost. The source of data is CSO/CSA. It contains dis-aggregated data up to four-digit industries for 20 years.

Man-year or man-hour: Which concept of labour input measures the productive content of labour is an issue. Is it the stock available for use in production (Man-year)? Is it the time in which stocks are available for production (man-hour)? Is it the compensation to the flow of services (wages)? There appears to be no conclusive prescription.

Labour input can be measured in man-year. But, man-year may not be a satisfactory measure of the number of persons working over the whole year. Such data only records the number of persons employed on the census day or during a short reference period of one or two weeks, which might ignore inter-seasonal variations. It is a weak approximation if employment is highly seasonal or irregular or when uneven changes have taken place during the year (Mabro and Radwan 1976:137-138). Silver proposed a monthly or quarterly count of workers; "the more frequent the count, the more appropriate is the resulting average for the purpose of calculating productivity" (Silver 1984:90).

However, due to many factors (incidence of absenteeism and sickness, change in the number of overtime workers, change in proportions of full time and part-time workers), employment in man-year is not a good measure of labour inputs in production, as the number of hours worked may differ among firms and vary from period to period (Mabro and Radwan 1976:138). They, therefore, propose to utilise man-hour. Even then, would the productive content of an hour of labour be identical so that labour will be a simple additive? The answer does not seem affirmative. Differences among labour in sex, age, ability, education, training, experience, devotion, etc., would be inevitable. Thus, the productive content of an hour of labour will not be identical. In this case, a simple additive of man-hour disguises the heterogeneous nature of labour force.

To make labour homogeneous, different approaches have been forwarded, like treating skills as a stock of intangible assets (Mabro and Radwan 1976) or weighing man-hour of different categories of labour force by their average earnings (Silver 1984; Mabro and Radwan 1976).

In this paper, wage is used as a measure of labour input because it is the simplest mechanism available to make labour homogenous. Data source is CSO/CSA.

Which capital: A converging idea on measuring capital in production had never been reached. Solow, stressing on the measurement problem, said "the capital time series is the one that will really drive a purist mad" (Solow 1957:314). Capital input in production is measured through estimate aided by some proxies. The proxy measures are still debatable.

One area of controversy is its coverage. There is no agreement on it. The coverage extends as wide as `all human and man-made assets' and as narrow as only 'machinery'.

Another controversy is on the valuation of capital stock. Walters stated that

> ... the most intractable difficulties are involved in measuring capital. In a mythical world where all machines are the same overtime, the ideal measure would appear to be the number of homogeneous machines.... The main difficulties... arise from the fact that the stock consists of various kinds of machines, buildings and land at different stages of their life cycles. Combining these into a monetary measure involves not only all these social index number problems but also difficulties, which are peculiar to capital (Walters 1963:23).

Indeed, to aggregate a heterogeneous stock of capital requires the knowledge of the price of each item: "... the unit of measurement varies with rate of profit; the relative prices of equipment are determined by future profit expectations" (Walters 1963:23).

In most empirical studies, as Mabro and Radwan pointed out, first cost provides the basis of valuations. The normal procedure is to measure capital value through perpetual inventory system and then deflate it by price index. Another alternative is valuation at current prices, which include:

> ... First, collecting the valuation for fire insurance, second, multiplying valuations for estate or inheritance duties by the reciprocal of suitable specific normality rates, and third, multiplying the property income stream by reciprocal of the estimated rate of return...(Walters, 1963:24)

The choice among these alternatives depends mainly on the weights given to quality and cost changes and on data availability.

The other debate is on the question of whether changes in capital inputs are proportional to changes in the gross or to changes in the net capital stock. There are some (Walters 1963; Mabro and Radwan 1976) who prefer gross. The main argument of those who propose for gross concept is that a machine or a building does not decline over time in the way implied by the usual depreciation methods. They also stated that net stock suffers from the arbitrariness involved in the concept of depreciation (Mabro and Radwan 1976:152).

On the other hand, there are others who argue for net rather than gross; their main argument is that capital input is proportional not to that of gross but to that of net. For instance, Silver (1984:127) stated that the value of capital stock in any period is given by the value in an initial period plus additions to and subtractions from the stock in each respective period. Kendrick argues for net capital as follows:

> Real stocks net of accumulated depreciation allowances are taken as a better measure of a basic capacity to contribute to production than gross stocks... Studies have shown that the gross output capacity of various types of machinery tends to fall with age, and the repair and maintenance charges rise so that the contribution to net revenue product of groups of items over time is roughly approximated by the gradual decline in the depreciated real value of stock shown by the usual depreciation accounting procedures reflected in the national accounts (Kendrick 1982:35)

The choice between gross or net capital varies according to weights given to each factor. In this paper, net fixed asset is employed due to lack of data.

Issues on inflation: The main source of data is "the Results of Surveys of Manufacturing and Electricity Industries" published by the Central Statistical Authority for various years (1976-1995). But data in these documents are at current prices. When value-added, wages and fixed assets are employed in this paper, it is on the understanding that they reflect quantity concept. Value reflects quantity if the effect of price is removed. Converting nominal values into real ones by using deflator can do this. In this paper, however, inflation is not taken into account because of strong conviction that proxy-deflating mechanisms distort results worse than price movements in the context of Ethiopian manufacturing sector.

Deflating using consumer price index would not be appropriate when output is value-added at factor cost. Prices in the manufacturing sector (which are dominantly public) were regulated and even if there were some price adjustments, it was mainly to counterbalance increments in intermediate costs and indirect taxes. Thus, when taxes and intermediate inputs are excluded, the fear of price fluctuation would be minimised.

Value-added increment that arises from average wage increment would not necessarily be ascribed to inflation; average wage shall increase overtime to capture the ever-increasing quality of labour. Profit was deliberately undermined since output prices were usually fixed for a long period of time (at least pre-1991) while intermediate inputs (mostly imported) were subject to price effect.

3.4. Results

In order to account for the nature of technical progress, three of the above-mentioned specifications are employed here: Katz specification, augmented Translog version and that of Hildebrand and Liu specification. That of Heathfield and Wibe method of estimation is not employed in this paper for lack of easy estimation techniques. For the three of the specifications, i.e. Equations [15], [16] and [18], two data sets are considered. One is a time series aggregate data set, which is the summation of all sub-sectors, and which assumes homogeneity among sub sectors. The other data set is the longitudinal data set (a time series data set of sub-sectors) that gives us 19 sub-sectors with 25 years of observation, excluding those with negative value-added observations.

Equation [16] is run using OLS. Relative factor share (π) is the ratio of labour to capital share (π_L/π_K). Capital-labour ratio is net fixed asset per unit of labour cost. The estimation is made using both aggregate data (which assume homogeneity among sub-sectors) and using longitudinal data. For the aggregate data, which is mainly a time series, regression with Newey-West standard errors (NWSE) is used (in built-in STATA 7) since it assumes that the error structure could be heteroscedastic and autocorrelated with lags. The result is reported in Table 2a.

Table 2a: Aggregate Data—Regression with NWSE of Equation 16

Regressors	Coefficients	T-Ratio	P Value	F-Ratio	Lag
- Con	0.5784	3.53	0.034	9.94	22
- T	0.0451	4.28	0.000		
- Ln(π)	-0.1043	-2.26	0.002		

For the disaggregate data which is mainly a cross-sectional time series, regression with panel corrected standard errors (PCSE) is used (in built-in STATA 7) since it assumes that the disturbances could be heteroscedastic and contemporaneously correlated across panels. The result is reported in Table 2b.

Table 2b: Panel Data—Prais-Winsten Regression of Equation (16) with PSCE

Regressors	Coefficients	Z-Ratio	P Value	Wald-Ratio
- Con	0.7120	3.62	0.000	8.6
- T	0.0263	2.23	0.026	
- Ln(π)	-0.0702	-1.95	0.051	

From the table, it is clearly seen that the significance of the coefficients as well as the signs remain consistent when one uses aggregate and panel data sets. But there is a difference in the size of the coefficients. While the coefficient for π is -0.07 in the case of panel data, it is -0.10 in the case of aggregate data. The reverse is true for size of the coefficient of T. It is only 0.0263 in the case of the panel data while it is about .0451 for the aggregate data.

Model (17) is run by OLS following the same line as that of Model (16) using both aggregate and panel data. The result of the regression with Newey-West Standard Errors is reported in Table 3.

Table 3a: Aggregate Data—Regression with NWSE of Equation [17]

Regressors	Coefficients	T-ratio	P-value	F-ratio	Lag
- Con	-1021.8	-4.76	0.000	3132.4	10
- T	-15.42	-9.07	0.000		
- T^2	-0.0569	-7.90	0.000		
- LnW	137.45	4.91	0.000		
- LnK	38.78	1.91	0.076		
- LnW^2	-5.63	-4.90	0.000		
- LnK^2	-1.362	-2.77	0.014		
- LnW*LnK	-0.511	-0.28	0.784		
- T*LNW	0.9248	8.52	0.000		
- T*LNK	0.3853	2.85	0.012		

The result of Prais-Winsten Regression of Equation [17] with panel corrected standard errors for the cross-sectional time series data (19 sub-sectors with 25 years of observations, excluding those with negative value-added observations) is reported in Table 3b.

Table 3b: Panel Data—Prais-Winsten Regression of Equation {17} with PSCE

Regressors	Coefficients	Z-ratio	P-value	Wald-value
- Con	3.466	1.51	0.131	498.1
- T	0.103	1.53	0.127	
- T^2	0.023	1.93	0.054	
- LnW	0.210	0.35	0.728	
- LnK	0.173	0.42	0.672	
- LnW^2	-0.025	-0.37	0.712	
- LnK^2	-0.063	-2.11	0.035	
- LnW*LnK	0.125	1.64	0.102	
- T*LNW	-0.014	-1.08	0.278	
- T*LNK	-0.002	-0.24	0.809	

Estimate of coefficients on aggregate data and panel data are dissimilar both in size and sign in most cases. For example, while the coefficient of LnW is 137 in the case of aggregate data, it is only 0.21 in the case of the panel data set. The same is true with respect to sign. While the sign is positive in the case of aggregate (the coefficient for T*LnW), it is negative in the case of panel and the reverse is true for the coefficient of T^2. Surprisingly, most of the coefficients in the case of the aggregate data set are statistically significant at 10 percent significance level. It is only the coefficient for capital, which is insignificant.

With regard to embodiment, equation (19) is run using both aggregate and panel data. Different alternatives are also assumed regarding the carriers of technical progress; technical progress is embodied in labour, capital or in both labour and capital but at different rates. The result of the estimate using aggregate data with the same technique as that of the above is reported in Table 4a.

Table 4a: Aggregate Data—Regression with NWSE of Equation [38]

Regressors	Coefficients	T-ratio	P value	F-ratio	Lag
- Log r log W	0.0438	0.78	0.444	11.24	10
- log R log K	0.0995	4.34	0.000		
- con	13.794	48.63	0.000		
- log W	0.9556	5.71	0.000	38.14	20
- log R log K	0.03306	4.20	0.000		
- con	1.57521	0.73	0.472		
- Log r log W	-0.1692	-4.66	0.000	186.61	12
- log K	0.88248	9.59	0.000		
- con	0.68909	0.48	0.637		

The result of Prais-Winsten Regression of Equation [19] with panel corrected standard errors for the cross-sectional time series data (19 sub-sectors with 22 years of observations, excluding those with negative value-added observations and deviant observations) is reported in Table 4b.

Table 4b: Prais-Winsten Regression of Equation (38) with PSCE

Regressors	Coefficients	T-ratio	P-value	Wald-value
- Log r log W	-0.00131	-0.28	0.777	0.22
- log R log K	0.00160	0.40	0.691	
- con	9.4808	59.72	0.000	
- log W	0.94461	21.87	0.000	478.47
- log R log K	0.00447	1.47	0.143	
- con	1.40955	3.66	0.000	
- Log r log W	-0.00141	-0.28	0.779	45.79
- log K	0.25189	6.76	0.000	
- con	7.3066	19.86	0.000	

As one can see in Table 4, relevant coefficients are either not statistically significant (the case of log r log W and log R log K in the case of panel) or theoretically meaningful (the negative value for log r log W). Those coefficients, which are statistically significant in some of the specifications, are near to zero. In fact, there appears no significant reason to choose one from the other. This could mainly be because of the fact that there was no technical progress registered by the manufacturing sector for the last two and half decades. In fact, if we look into the trends of total factor productivity (the ratio of value-added in the national account concept at factor cost and the combined factor inputs – labour and capital – with their respective factor income shares) for the last twenty-five years, it was declining, indicating the absence of technical progress in the sector.

Table 5: TFP Using Different Factor Shares and Labour Input

Year	Case 1	Case 2
1975/76	1.1569	1.0836
1976/77	1.3046	1.2070
1977/78	1.5407	1.4135
1978/79	1.8368	1.6570
1979/80	2.2049	1.9648
1980/81	2.0958	1.8735
1981/82	1.9800	1.7505
1982/83	1.9287	1.6870
1983/84	1.9533	1.7054
1984/85	1.3020	1.1734
1985/86	1.4760	1.3170
1986/87	1.5473	1.3808
1987/88	1.4309	1.2543
1988/89	1.5981	1.3971
1989/90	0.9450	0.8444
1990/91	0.6830	0.6228
1991/92	0.5035	0.4557
1992/93	0.8081	0.7324
1993/94	0.9962	0.9117
1994/95	1.1478	1.0410
1995/96	1.0763	0.9887
1996/97	0.9415	0.8722
1997/98	0.7531	0.7018
1998/99	0.7239	0.6831
1999/00	0.6907	0.6555
Growth	-4.037%	-3.909%

Source: Own computation.

In summary, the nature of technical progress using the above approaches becomes unclear. It tends to vary on the methodology and the data set utilised, as one can see from Table 6. Table 6 is constructed by looking into the significance of the coefficients, which contains information about the nature of technical progress regardless of the significance of others. The significance of the model as a whole is, however, a pre-condition.

Table 6: Nature of Technical Progress

	Data set	
Models	**Aggregate**	**Panel**
Equation 34	L-saving	Labour-saving
Equation 35	L- and K-using	Stat. insignificant
Equation 37	Unfit	Unfit

The coefficient for T in Equation [16] is positive (0.0451) and significant at 5% level using aggregate data implying that labour efficiency is 4.51% higher than capital, which indicates labour-saving nature of technical progress. It is also positive in the case of panel data and significantly different from zero indicating labour saving nature of technical progress. In the case of Equation (17), the coefficients for T*LnW and T*lnK using aggregate data are positive indicating both labour and capital consuming nature of the production system of the Ethiopian manufacturing sector. For panel data, however, the coefficients for both become insignificant though the sign for the former changes to negative. Regarding Equation [19]. there is no indication as such.

The result summarised in Table 6 indicates that the production process of the Ethiopian manufacturing sector seems more of labour saving and frequently factor input using. In fact when we look into the source of manufacturing output growth in Table 7, the contribution of total factor productivity to output growth is negative.

Table 7: Source of Manufacturing Output Growth for 1975/76-1999/00

Items		**1976-1990**	**1993-2000**	**1976-2000**
Growth in %	Labour	7.23%	6.67%	6.44%
	Capital	8.06%	18.66%	10.91%
	Output	5.12%	14.50%	6.43%
Factor Share	Labour	34.91%	32.07%	34.56%
	Capital	65.09%	67.93%	65.44%
Contribution to Growth	Labour	42.0%	15.70%	35.68%
	Capital	87.29%	94.83%	108.69%
	TFP	-29.29%	-10.52%	-44.38%

Source: Own computation.

Much of the output growth emanates from capital. In fact, the output growth could not compensate the capital consumed. Such labour and capital wasting nature of the production process of the Ethiopian manufacturing sector is a sign of danger undermining its competitiveness in the global market. With such type of production technique, globalisation will be a great threat to Ethiopia.

4. CONCLUSION

The conclusion and implication to be drawn from the foregoing, however, needs some caveats, at least, from two perspectives. First, it is based on neoclassical models and second its database assumes some level of aggregation. Neoclassical models usually use strict and stringent assumptions like production function, profit maximization, perfect competition, free and immediate access to information and zero transaction costs. All these assumptions are nearly untenable in the Ethiopian context. The conclusion arrived at and the implication to be drawn from such a setting, thus, might be erroneous. Secondly, the methodology employed assumes learning as a simple function of time, whereas case studies proved that a process of technical progress does not proceed at a constant rhythm (Herbert-Copley 1990:1460). Furthermore, the way technical progress is computed does not entertain quality improvement, productivity increase in intermediate input and fluctuations in capacity utilization for factors beyond the control of firms. Besides, technical change is measured by its impact on productivity and not by its absence or presence on the hardware or software side of production. Technical progress might occur without significant impact on productivity. Thirdly, the results arrived at and the implications rest on aggregate data (data is collected at three-digit industry level). But the process of technical progress across firms will not be uni-directional, which the results of this paper assumes. Heterogeneity is certain and generalization without due consideration to firm-specific characters might be misleading.

Given these caveats, one point is clearly observed in this study. The production technology in general was capital consuming and labour saving contrary to the theory of initial factor endowments of the country. This implies then that choice of technology was not appropriate to the prevailing conditions of Ethiopia. This in turn implies that enterprises in Ethiopia lack the capability of technological acquisition. This in turn implies that, if Ethiopia has to industrialise, manufacturing enterprises have to build the necessary technological capabilities and the government should install the necessary public goods, incentives and institutions.

The premise here is that "technological knowledge is not shared equally among firms, nor is it easily imitated by or transformed across firms. Transfer necessarily requires learning (Lall 1992:160). As a result, acquiring technological knowledge requires firstly, experience in production, and secondly, investment on learning, and those firms with these elements produce the required capability. Raut reported, " ... while knowledge from private R & D capital spills over to create public domain knowledge, a firm must invest in private R & D to acquire the technical capability needed to make use of the public domain knowledge to enhance productivity" (Raut l995:2). Utilising public domain knowledge fruitfully has costs, but the cost will be minimal for those firms, which have accumulated the stock of technological knowledge through considerable investment in R & D in the past (Raut 1995).

This process is the deliberate effort of the firm to adapt technology to new conditions, to improve it slightly or very significantly, and this process might pass through three stages of capability: Production, investment and innovation (Lall 1992; Dahlman *et al.,* 1987). Production capability includes production management—ability to oversee and improve operations; production engineering—ability to obtain information (about systems of raw material control, production scheduling, quality control) and act to optimise Operations; trouble-shooting to overcome problems and adapting process and products to increase productivity; repair and maintenance of physical capital. These capabilities can be gained from gathering and interpreting information from the production system, from attempting adaptations and modifications, from understanding why some work and others do not, and from keeping records to preserve such information. And it entails continuous and systematic efforts and resources; it shall not just happen when shocked by changes in inputs or production markets. The process may take up to 20 years to acquire its full range (Dahlman *et al.*, 1987:764-765; Lall 1992:168-169).

Investment capabilities include the skills needed to identify, prepare, obtain technology for design, construct, equip, staff and commission an expansion which determines the capital cost, the appropriateness of the scale, product mix, technology and equipment selected which in turn affects the efficiency with which it will operate (Lall 1992:168). Innovation capability consists of major and minor innovations including improvements in existing technology; and, acquiring the former two capabilities is the main impetus to develop some capabilities in innovation. These capabilities are important for diversification and change and every firm has to give due respect for efforts to attain these capabilities. A firm that fails to achieve these capabilities will fail to survive. Lall argued

> if a firm is unable by itself to decide on its investment plans or selection of equipment, process, or to reach minimum levels of operating efficiency, quality control, equipment maintenance or cost improvement, or to adapt its product designs to changing market condition, or to establish effective linkages with reliable supplies, it is **unlikely** to be able to compete effectively in open markets (Lall 1992:168)

The pace of acquiring these capabilities by firms depends on the level of development the economy is in, physical and human capital development, national technological efforts, incentives, institutions and government policies, all of which are not the domain of individual firms, but the environment which they are supposed to live in.

Firm level technical capabilities can be acquired, however, only if there are sufficient entrepreneurial capabilities, deep industrial experiences, proper incentives and adequate institutions. The government has to provide all these in sufficient magnitude. These capabilities include the launching of physical investment, the provision of human capital and the undertaking of technological efforts. Lall reported that "these three are strongly inter-linked in ways that make it difficult to identify their separate contributions to national performance, but they do not always go together" (Lall 1992:170). The one without the other will not exert a sufficient impact, or the existence of the one does not necessarily bring into existence of the other. Of course, physical investment is a pre-requisite: for industry to exist, plants and equipment are necessary. The undertaking of physical investment in Ethiopia was hindered by lack of the domestic investment capabilities, which in turn is caused by lack of entrepreneurial capability. The extent to which the private sector participates and the experience on industrial activities would have been important to enforce the development of entrepreneurial capabilities.

The size of the informal sector in Ethiopia might give an impression that there is no shortage of entrepreneurial drive. But the drive to profit from opportunity might not *per se* be the same as the entrepreneurial capability required to organise, set up and run modern industry, which requires larger scales, longer time perspectives, more advanced technologies and more complex organisations than traditional crafts or informal sector activities (Lall 1992:116). They rather favour rent seeking and trade activities, which produce quick returns. The other point is that the private sector was stifled by wrong economic policy for about two decades that impedes to produce its impact on physical investment.

Now, the move in Ethiopia is already on progress in the right direction but efforts should continue to be made further by the government to increase the participation of the private sector (not necessarily through privatisation) and the process of learning entrepreneurial capabilities. This entails commitment beyond installing a favourable enabling environment especially in identifying basic barriers to industrial entrepreneurial capability and initiating selective intervention on industrial activities. Protection of selected manufacturing enterprises, promoting technological efforts of industrial enterprises, subsidising firm level research and development are few important areas that the government has to look into in the Ethiopian context.

Regarding protection, the government of Ethiopia has taken trade policy reforms. The reform has reduced the extent of protection in most firms; and inter-firm variations of protection rate have decreased. Most enterprises are exposed to competition both from domestic markets (by encouraging private investment which was stifled deliberately) and from imports (by liberalizing trade). The move could be in the right direction but looks gross and indiscriminate. Quoting Lall (1992:125) here is appropriate.

> Given the inherent costs and duration involved in building up capabilities in new, complex industrial activities, and given the differences between technologies, there is no reason to argue that all industries should be protected equally... More difficult technologies call for higher protection, and activities, which have high linkages with others, call for broader protection to embrace related industries, which are also undergoing learning. Similarly, activities that generate higher externalities need more support because investors cannot appropriate all the benefits.

Competition is necessary but it is a double-edged weapon. Too much competition can wipe out firms that cannot finance the costs of capability acquisition. Thus, the adjustment in Ethiopia must be selective and gradual.

The other important element that the government should focus on is education and training. Its primary importance is its impact on entrepreneurial capability; a person with high level formal education is better placed to adapt, understand, learn, use and create ideas. Entering into a more demanding activity calls for increasing level and technical specialisation in education. Quality of education and its technical orientation (vocational training) are quite important which currently Ethiopia lacks. Firm level training is crucial and efforts made at the firm level to create skills and train workers could make a difference on TFP but firms usually are reluctant to invest on training. Regarding the importance of in-firm training and the role of government in providing it, Lall said

> Since there is a serious risk of private under-investment in training at the firm level when labour is mobile, human capital development requires measures to induce more investment to support employee training, by firms individually or collectively, or by governments where private agents consistently under-invest. These measures may be functional, applied to all activities, or they may be selective, targeting emerging sectors (Lall 1992:181).

As to what measures to be taken, when and to what extent, it shall depend on individual cases.

Even if labour is trained and physical investment is made, these will only be productive when combined with technological efforts made by the government to guide firm level efforts.

As well, there must be industrial institutions to promote inter-firm linkages in production, technology or training, to provide support to smaller enterprises, to help firms to restructure and update. There has to be technological institutions to remedy market failures especially in the area of information on sources of technology since technological information does not exist everywhere, nor are the international markets of technology competitive.

As such, there is no institution set up to supply information about technology or markets while selecting appropriate technology - technology that is easy to adapt, assimilate and change to local conditions - rests upon information and the ability to use that information effectively. Because information, by its character, is a public good and characterized by large economies of scale in collecting and organizing information, the private actors under-invest on it since they cannot appropriate all the benefits of their activity. This justifies the need for the government to subsidize the collection and dissemination of technological information or set up such institutions and provide to those in need of at affordable charges.

NOTES

1. Measuring technical progress via its impact on output can be outlined as follows. Assume a general production function for two consecutive periods of the form:

$$Q_t = A_t F(L_t, K_t) \qquad [1]$$

and

$$Q_{t+1} = A_{t+1} F(L_{t+1}, k_{t+1}) \qquad [2]$$

Assume Y as output at time t+1 solely due to L_{t+1} and K_{t+1} inputs, i.e.,

$$Y = A_t F(L_{t+1}, K_{t+1}) \qquad [3]$$

A_t measures the efficiency level at time t. The change from Q_t to Y is due to the change in L and K, and the change from Y to Q_{t+1} is due to 'technical progress'. Rate of technical progress will, therefore, be:

$$\frac{Q_{t+1} - Y}{Y} = \frac{A_{t+1}}{A_t} - 1 \qquad [4]$$

Technical progress can, as well, be estimated using a general production function of the form:

$$Q = F[L(t), K(t), t] \qquad [5]$$

where t is time. The change in output overtime is given by

$$\frac{dQ}{dt} = \frac{\partial F}{\partial L}\frac{dL}{dt} + \frac{\partial F}{\partial K}\frac{dk}{dt} + \frac{\partial F}{\partial t} \qquad [6]$$

The change in output is decomposed into two: Change in output due to a movement along the production function and the change in output due to a shift in the production function or due to disembodied technical progress (see Intriligator, 1978:289). Dividing Equation [6] by Q and converting to proportionate change yields:

$$\frac{1}{Q}\frac{dQ}{dt} = \frac{L}{Q}\frac{\partial F}{\partial L}\frac{1}{L}\frac{dL}{dt} + \frac{K}{Q}\frac{\partial F}{\partial K}\frac{1}{K}\frac{dk}{dt} + \frac{1}{Q}\frac{\partial F}{\partial t} \qquad [7]$$

The first two terms on the right are the proportionate rate of change of the two inputs, each weighted by their respective elasticity of output. The third term is the proportionate rate of disembodied technical progress. Assuming that the elasticity remains fairly constant overtime and the proportionate rate of disembodied technical progress is constant at a rate m, Equation [7] can be converted into the following:

$$\frac{1}{Q}\frac{dQ}{dt}=a\frac{1}{L}\frac{dL}{dt}+b\frac{1}{K}\frac{dk}{dt}+m.........\quad [8]$$

where a and b are the labour and capital elasticity of output respectively. Solving for m and assuming dt=1, Equation [8] turns out to be:

$$m=\frac{dQ}{Q}-a\frac{dL}{L}-b\frac{dk}{K}........\quad [9]$$

Rate of technical progress is thus the difference of output change from the combined input change; inputs are combined weighted by their respective elasticity of output. The above result is implied by a Cobb-Douglas production function of the following:

$$Q=A_o e^{mt} L^a K^b........\quad [10]$$

where Q= output, L= labour input, K= capital input, m= proportionate change of Hick's neutral disembodied technical progress, A_o = initial efficiency parameter, t= time and a and b are partial elasticity of output with respect to L and K respectively (a and b are non-negative).

As well, from equation (5), assuming a neutral technical progress, time can be factored out in order to write it as:

$$Q=A(t)\,F[K,L].......\quad [11]$$

A(t) measures the cumulative effect of shifts over time (see Solow 1957:312). And it is easy to arrive at:

$$\frac{dQ}{Q}=\frac{dA}{A}+a\frac{dL}{L}+b\frac{dK}{K}..........\quad [12]$$

where a and b are the relative shares of capital and labour. If one takes the total differential of equation (11) with respect to time, it will be:

$$\frac{dQ}{dt}=\frac{dA}{dt}F(k,L)+A\frac{\partial F}{\partial L}\frac{dL}{dt}+A\frac{\partial F}{\partial K}\frac{dK}{dt}........\quad [13]$$

If Q divides the whole expression, it turns out to be:

$$\frac{1}{Q}\frac{dQ}{dt}=\frac{1}{Q}\frac{dA}{dt}F(k,L)+\frac{A}{Q}\frac{\partial F}{\partial L}\frac{dL}{dt}+\frac{A}{Q}\frac{\partial F}{\partial K}\frac{dK}{dt}.......\quad [14]$$

After simplifying the first term of the right side expression, it will take the form:

$$\frac{1}{Q}\frac{dQ}{dt}=\frac{dA}{Adt}+\frac{A}{Q}\frac{\partial F}{\partial L}\frac{dL}{dt}+\frac{A}{Q}\frac{\partial F}{\partial K}\frac{dK}{dt}\text{.........} \quad [15]$$

Since

$$A\frac{\partial F}{\partial L}=\frac{\partial Q}{\partial L}\ldots \quad [16]$$

and

$$A\frac{\partial F}{\partial K}=\frac{\partial Q}{\partial K}\ldots \quad [17]$$

Assuming dt = 1, Equation [15] will be:

$$\frac{dQ}{Q}=\frac{dA}{A}+\frac{\partial Q}{\partial L}\frac{dL}{Q}+\frac{\partial Q}{\partial K}\frac{dK}{Q}\ldots \quad [18]$$

Multiplying the last two terms by L/L and K/K respectively, the expression will take the form:

$$\frac{dQ}{Q}=\frac{dA}{A}+\frac{\partial Q}{\partial L}\frac{L}{Q}\frac{dL}{L}+\frac{\partial Q}{\partial K}\frac{k}{Q}\frac{dK}{K}\ldots \quad [19]$$

Defining a and b to be labour and capital elasticity of output respectively, i.e.,

$$a=\frac{\partial Q}{\partial L}\frac{L}{Q}\text{.....} \quad [20]$$

and

$$b=\frac{\partial Q}{\partial K}\frac{K}{Q}\text{.......} \quad [21]$$

through substitution one can arrive at Equations [9] and [12].

2. Least cost efficient input use in production requires the condition (assuming perfect factor and product market):

$$\frac{w}{r}=\frac{E_L^{-\rho}(Y/L)^{(1+\rho)}}{E_K^{-\rho}(Y/K)^{(1+\rho)}}\ldots \quad [1]$$

Solving for K/L, Equation [1] will take the form:

$$\frac{K}{L}=(\frac{w}{r})^{\sigma}(\frac{E_L}{E_K})^{(1-\sigma)} \quad ... \qquad [2]$$

Multiplying both side by $(L/k)^{\square}$ yields:

$$\frac{K}{L}(\frac{L}{K})^{\sigma}=(\frac{w}{r}\frac{L}{K})^{\sigma}(\frac{E_L}{E_K})^{(1-\sigma)} \quad ... \qquad [3]$$

Labelling Π_L and Π_K as the shares of labour and capital respectively and solving for K/L, Equation [3] can be written as follows:

$$\frac{K}{L}=(\frac{wL}{rK})^{(\frac{\sigma}{1+\sigma})}(\frac{E_L}{E_K})=(\frac{\pi_L}{\pi_K})^{(\frac{\sigma}{1+\sigma})}(\frac{E_L}{E_K}). \qquad [4]$$

Assuming that changes in E_L/E_K, the relative efficiency of labour, take place at a constant geometric rate (Π_L- Π_K), where Π_L and Π_K are the respective constant geometric rate of growth of the efficiency of labour and capital, then:

$$\frac{E_L}{E_K}=A_o\exp(\varepsilon_L-\varepsilon_K)t.. \qquad [5]$$

where A_0= $E_L(0)/E_K(0)$ which represents the relative efficiency of labour at the base period. Substituting Equation [5] into Equation [4] yields a regression model in logarithmic form, which can be written as follows:

$$\text{Log}\frac{K}{L}=A_o+\frac{\sigma}{(1+\sigma)}\text{Log}\,\pi+(\varepsilon_L-\varepsilon_K)t... \qquad [6]$$

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