E C O N O M I C S B U L L E T I N

Technological advances and industrial characteristics:Some evidence from developed and developing countries

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Abstract

The need of technological advances for competitiveness is rather well known. However, the structural impacts of technological improvements on unemployment remain largely unexplored in the existing literature. The paper analyses the complex interlinkages among technological adaptation, labour productivity gains and scale expansion. It highlights the two opposing effects of technological improvements and labour productivity on employment. The paper demonstrates the role of scale expansion both through the logic and empirical findings. It is argued that to achieve positive employment effects of technological modernization, via productivity gains and scale expansion, a greater degree of global trade and investment integration is needed. It also highlights the need for strengthening labour productivity and wage rate linkages to simultaneously address the supply and demand side effects of technology on economic growth. In nutshell, the paper argues for building on the new growth theories.

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1. Introduction

The imperatives of globalization have highlighted the importance of technological advances and changes in industrial organization. However, in this context, a number of conflicting trends have emerged. On a positive note, changes in production processes have led to the introduction of several new products. They have also resulted in sharp cost reductions and improved growth performance in different sectors of an economy. In terms of adverse effects, these have also implied various labour market ramifications that may hinder the very development process.

For achieving competitiveness, enterprises are often under pressure to restructure their production activities. These have the potential to effect structural changes in production methods by adapting to latest technology. Such structural changes get reflected in different industrial characteristics such as employment levels, wage rates, labour productivity and scale of operation. In turn, the structural shifts influence not only the supply-side efficiency but also the scenario on the demand side. At the core of it, concerns are expressed with regard to the labour-displacing effects of technologies. These processes need to be analysed for both the developed and developing regions in order to address the employment-related policy issues.

Many of these issues need to be considered in the context of recent theoretical advances. The theories that deal with the positive role of technology in terms of growth outcomes need further extension. The basic contention of this paper is that unless the adaptation to new technologies is associated with favourable implications for employment growth and income generation, demand-deficiencies in the economic system may hinder the growth-propelling effects of technology. This happens due to the income losses that are incumbent upon job losses. This is by no means to deny that technology has an important role to play in an economy's growth process. The challenge is to incorporate both the growth-inducing and growth-limiting effects of technological modernization. An analysis of this kind would also shed some light on the problems of unemployment in the developed countries. It may also reveal whether this problem is due to an over-emphasis on the technological modernization or the imports from the developing countries.

Against this backdrop, Section 2 deals with some of the major analytical issues pertaining to technology-unemployment linkages. The issues are explored empirically in the subsequent sections for which the details of data sources used and variables included are presented in Section 3. The interlinkages of different labour market variables are analysed in Section 4 on the basis of the empirical results. Some broad conclusions are presented in Section 5.

2. Major issues

It is evident from the literature-survey on the subject that research has been rather inconclusive on the implications of technological modernization, especially for employment, wage rate and labour productivity levels. These are analyzed briefly below.

2.1 Shift in choice of technique and employment effects

Greater economic openness is often associated with a shift in the choice of technique of production. The imperatives of quality improvements and export competitiveness often necessitate a shift in the industrial production methods towards more capital- and technology-intensive techniques. One obvious hypothesis would be that such a shift is labour displacing.

Nevertheless, if scale economies are brought into the analysis, any expansions in output levels can reverse the process – a fact that should not be left out in the analysis.

The analytical developments in this context are categorized by Petit (1995) in three strands of thoughts: (a) Solovian tradition (b) Neo-Keynesian developments and (c) Schumpeterian approaches. Neither Keynes nor Schumpeter addressed the employment effects of technological change directly. In the neo-classical growth model developed by Solow there is no technological change and employment is assumed to be equal to the supply of labour. Thus, unemployment does not arise. In this sense, the implications of technological change for employment growth are not captured in any direct way in these theoretical strands. A major improvement in Solow's model has been made in the new growth theory. This has focused primarily on treating technological change as an endogenous process but again the implications of technological change on employment levels are not spelt out (Romer, 1986; Lucas, 1988 etc.).

The neo-Keynesian developments have assumed that operations of the economic agents are not necessarily rational and prices are thus rather sticky – unlike the Solovian assumptions. Consequently, markets are either demand or supply constrained. In such situations, technological change could lead to unemployment. The multi-sectoral Keynesian models have tried to assess the employment effects of technological changes (e.g. Leontief and Duchin, 1986; Whitley and Wilson; 1987 among others).

Recent Schumpeterian approaches have been different from the earlier-mentioned two approaches in terms of drawing extensively on the innovation and diffusion aspects of technological change. In the earlier two approaches, technological change had been a rather abstract concept (Petit 1995). Even the Schumpeterian approach has not addressed the issue of technological change and employment in any direct manner. However, its contribution lies in highlighting the fact that technological change does not only shift the capital-labour ratio but also influences the skill structure of jobs. Hence, it has been observed that the problems associated with the adjustments of the skill structure with the change in production processes can also generate unemployment (Katsoulacos 1986; Panchamukhi and Das, 1999 among others).

In short, there has been insufficient empirical work on the employment effects of technological change, perhaps because none of the three approaches has dealt with this issue in any explicit manner. In this context, the emphasis laid by the new growth theories on economic openness provides some lead on which further work is needed. This body of literature has the potential to help understand the policy mechanisms that can minimize the labour-displacing effects of technological change. This may be possible by understanding the complex interlinkages among technological modernization, labour productivity gains and scale economies.

2.2 Labour productivity

In this section, the relationships among technological advances, production-efficiency (captured by labour productivity improvements) and scale effects are analyzed. Greater economic openness has the potential for bringing about efficiency gains in production processes through technological modernization efforts. However, the literature on efficiency gains makes a distinction between allocative and technical efficiency and a favorable impact of economic openness on the latter has remained a debatable issue.

Labour productivity is considered as a representative of general improvement in production efficiency and a reliable indicator of competitiveness, especially in tradable

sectors (Haque, 1995). One of the reasons for this viewpoint is the existence of considerable empirical evidence to show that labour and capital are complementary and their contributions to output cannot be separated. In addition, the range of factor combination possibilities in an industry is often much narrower than it is in the typical textbook exposition of production iso-quants. Further, changes in labour productivity in an industry over a period of time can be considered to be a consequence of technological accumulation. Hence, labour productivity could be taken as a proxy for the influence of technological changes on different variables including employment.

Thus, the hypothesis that greater economic openness leads to labour productivity gains needs to be tested. In this context, two possible opposing effects of labour productivity gains on employment need to be understood (Das, 2005). The first effect is positive when labour productivity gains lead to greater demand for the productive labour therefore, employment expands. The process assumes that greater economic openness allows for scale expansion, leading to an increase in employment of the productive labour. The second effect of labour productivity gains could be negative for employment, especially in the absence of scale expansion. In such a scenario, labour productivity increases could actually result in a lower demand for labour per unit of output. In other words, a fewer number of more productive workers would be required to produce the same level of output. This could result in employment contraction.

2.3 Wage-labour productivity link

In the context of the technology-employment linkages, it is important to explore the issues more deeply by analyzing the dynamics of wage-productivity linkages. This is particularly important from the point of view of the new growth theories. As per normative considerations, labour productivity changes should influence the level of wage rates in the same direction. However, if wage rates move less than proportionately vis-à-vis any rise in labour productivity (brought about by technological advances) this would render the wage-productivity link weak. On the other hand, it has been found that economic growth; investment share growth and productivity growth are the main determinants of real wage growth (Paus and Robinson, 1997).

A weak wage-productivity link could be due to institutional constraints. It could also be weak due to limits on scale expansion. However, in any case it would have deleterious implications for the quantity and quality of employment. Moreover, the weak interlinkages may have adverse effects on the demand side and economic growth outcomes.

2.4 Scale of operation

It is thus clear, that the interlinkages among technology improvements, labour productivity gains and increases in wage rates have important implications for employment. But at the centre of analysis of such implications is the possibility of scale expansion. It was noticed that if scale expansion is not possible, labour productivity increases could actually result in employment contraction. Hence, the importance of scale expansion requires further elaboration.

According to the strategic trade theory too, as propounded by Krugman and others, technological advances in an enterprise could lead to increasing returns to scale, which is reflected in technical efficiency or productivity growth. The economies of scale reduce cost per unit of output, which is manifested in higher value addition. Given the total number of employees, labour productivity measured as output (or value added) per worker rises.

The positive influence of technological adaptation on labour productivity improvements would result in favourable employment effects if scale expansion were possible. Due to the fact that size of the domestic market often acts as a constraint on scale expansion, the importance of external sector's openness gets pronounced. However, scale expansion could be limited even when a country pursues an export expansion strategy. Despite greater openness, due to demand constraint or protectionist measures in destination countries, exports need not provide adequate opportunities for scale expansion. Viewed from another angle, it is technically impossible to expand production scales by each country with the help of an export-oriented strategy, as each country would need partners that import. Therefore, to achieve positive employment effects of technological modernization, via productivity gains and scale expansion, a greater degree of global trade integration may be needed. So countries would have to trade more for stepping up the scales of production.

Scale effects need to be analysed also in the context of greater investment integration, globally (Sen, 1996). It is expected that with an increased openness of investment regimes, the presence of foreign affiliates also increase. These operate on a much larger scale and often employ more capital-intensive production methods (Kumar, 1994). While employment may increase due to larger scale of operation, it may decrease due to increased capital-intensity of production. Thus, the net effect needs to be studied as far as implications of investment integration for employment are concerned.

The forgoing discussion may be summarized to get the following relationships that need to be examined.

(i) An analysis of the relationship of employment with labour intensity, labour productivity and scale of operation is crucial for assessing the effects of technology on labour-related industrial characteristics. This would mean combining three hypotheses. Firstly, with an increase in technology intensity, employment falls. Second, labour productivity gains could result in both employment expansion as well as employment contraction. Third, scale effects offered by trade and investment openness influence favourably the employment levels. Therefore,

Employment = f (labour intensity, labour productivity, scale)

However, it may be added that such an analysis would be complete only when a distinction between skilled and unskilled works is made wherein wage rate also becomes a determinant of employment, especially in the skilled category. A lack of adequate data prevents us from including these variables.

(ii) Decreasing labour intensity resulting in employment contraction could have dampening effect on the level of wage rates.

(iii) Labour productivity gains are not always manifested in rising wage rates.

These hypotheses are tested and analysed in the subsequent sections.

3. Data Sources and Variables

Various volumes of the UNIDO Industrial Statistics were used as the main data-source. The variables taken under consideration are number of employees, gross output, value added, wages and salaries and number of establishments in the manufacturing sector. For each variable, 3-digit ISIC data was pooled for 28 sectors over a time-series of 15 years between 1985-2000. For arriving at constant prices, GDP deflator was obtained from

International Financial Statistics of the IMF. For some countries, if the data for 2000 was not available, data available for the latest year was used. An index of labour-intensity was constructed by defining it as the ratio of wages and salaries (numerator) to output minus wages & salaries (denominator), expressed as LI. The advantage of capturing labour-intensity as LI is embedded in the fact that it tries to take into account the quality of factors of production and not expressed merely in terms of a physical labour-capital ratio. The labour productivity is expressed as output per employee (LP) and output per establishment has been used as an indicator of scale of operation (SO). Any divergence between the rates of change in wage rate and labour productivity would denote the extent of linkages between the two. The developing countries included in the sample are S. Korea, Indonesia, Malaysia, Thailand, Bangladesh, India, Pakistan and Sri Lanka. From the developed world EU-15 is included in the sample. The econometric explorations took into account the regression specification tests and stability tests. To tackle the problems of stationarity associated with the panel data, Hadri-Test was performed.

4. Results: An analysis of relationships

The results for the manufacturing sector suggest that all the countries of the sample have experienced a shift in choice of technique over the period under consideration, although in different sectors. Sectoral details are not presented for the sake of brevity. It is also observed that employment growth has not been commensurate with output expansion in the sample countries' during the period. This could imply that broadly labour productivity has increased in the manufacturing sector.

Against this background, an attempt has been made to test the following relationship of labour intensity (LI) with labour productivity (LP) and scale of operation (SO) for the sample countries.

$$LI = f(LP, SO)$$
$$(?)\ \ (+)$$

A more labour intensive technique would generate higher employment. In addition, scale expansion would also lead to employment expansion. However, as the preceding discussion indicates there could also be two opposing effects of labour productivity gains, one implying employment expansion if scale expansion is allowed and another implying employment contraction in the absence of scale effects.

The results presented in Table 1 reveal that in the case of South Korea, Thailand, Bangladesh, India and Pakistan labour productivity has a negative sign and the coefficient is significant. This implies that an increase in labour productivity adversely influences labour absorption. It also means that labour productivity gains have been brought about by a shift in choice of technique in these countries towards a more technology intensive technique. In the case of Indonesia, Malaysia and Sri Lanka the coefficient is with the negative sign but not significant. On the other hand, the coefficient of the scale variable is also significant in the first set of countries and for Indonesia, Malaysia and Sri Lanka it is not significant.

If we include the changes in labour intensity into the analysis we find that in the case of Bangladesh and Thailand the loss of employment on account of labour productivity gains has outweighed gains in employment due to scale expansion. This is manifested in a decline in labour intensity. In the case of India, scale effects cancel the effects of labour productivity gains. This is due to the fact that the labour intensity has remained unchanged during the period under consideration. In the case of South Korea and Pakistan scale effects have dominated over the labour productivity effects, as labour intensity has increased. In the case

of Indonesia, Malaysia and Sri Lanka the variables are insignificant. It may be mentioned that R^2 has varied between countries and over time. This is expected, as just these two explanatory variables cannot explain the total variation in the dependent variable chosen.

The results presented in Table 2 reveal that in the case of most of the EU members, except Belgium and Netherlands, labour productivity has a negative sign and the coefficient is significant. This implies that in these countries an increase in labour productivity adversely influences labour absorption. It also means that labour productivity gains have been brought about by a shift in choice of technique towards a more technology intensive technique. On the other hand, the coefficient of the scale variable is also significant in several countries.

If we include the changes in labour intensity into the analysis and combine these observations we find that in several cases loss of employment on account of labour productivity gains has outweighed gains in employment due to scale expansion, as manifested in a decline in labour intensity. Variation in R^2 is similar to those found in the sample of developing countries due to reasons explained above.

This process would be economically beneficial from the demand side, if increases in labour productivity were matched with increase in wage rates as well. Often the influence of globalisation and technological modernisation is studied only to the extent that these manifest in labour productivity gains. However, the analysis must be extended beyond to examine the wage-productivity linkages.

To explore into this aspect, the elasticity of real wage rate with respect to labour productivity gains in real terms was obtained:

$$\text{Log } (L_2) = \alpha + \beta \text{ Log } L_1 + \mu$$

where, L_1 is labour productivity and L_2 is wage rate.

For the developing countries' sample, the results show that for all the countries the elasticity is less than 1 and it is statistically significant, too (Table 3). Except for Sri Lanka and Bangladesh, R^2 is also reasonably high. In the case of the EU-15, it is observed from Table 4 that for several countries in the sample the elasticity is less than 1 and it is statistically significant except for Greece, Italy, and Luxembourg. It is observed that the R^2 is also reasonably high for many countries. These results imply that wages rise less than proportionately as compared to the increases in labour productivity.

Since technological changes get reflected in labour productivity gains but not so much in wage and income gains, demand deficiencies could constrain their positive influence on economic growth. The problem gets aggravated because labour productivity gains are found to be influencing employment levels adversely, in many cases by outweighing the scale effects on employment generation.

5. Conclusion

The survey of existing literature and our empirical examination of hypotheses reveal that the employment effects of technological change have not been researched as extensively as desired. Our results suggest that labour productivity gains brought about by technological advances cannot be regarded always as a virtue of the globalization process Little attention has been paid to the employment contraction effects of labour productivity in the existing literature. The extent to which technological modernization brings about labour productivity gains is yet another dimension which has not been researched more deeply. Our results also

suggest that unless labour productivity gains get translated into increases in wage rates, the overall growth-effects of technological improvements might remain limited. This is because wage rate increases have crucial influence on the demand side. Unless wage rates increase in consonance with labour productivity gains, any improvements in the supply side efficiency would only result in inventories and further recessionary tendencies that may keep igniting the unemployment cycles.

What is more, the existing literature does not adequately take into account the employment contraction effects of labour productivity gains that may outweigh the employment generation effects of scale expansion. Nevertheless, the importance of scale expansion comes out as a crucial factor in harnessing the growth-inducing effects of technology. Due to the fact that size of the domestic market often acts as a constraint on scale expansion, the importance of external sector's openness gets pronounced. However, scale expansion could be limited even when a country pursues an export expansion strategy. Despite greater economic openness, due to demand constraint or protectionist measures in destination countries, exports need not always provide adequate opportunities for scale expansion. Viewed from another angle, it is technically impossible to expand production scales by each country with the help of an export-oriented strategy, as each country would need partners that import. Hence, to have positive employment effects via productivity improvements and scale expansions, a greater level of global trade integration is needed. In such a scenario, countries would have to trade more since one country's exports are another country's imports. Further, scale effects need to be analysed also in the context of greater investment integration, globally.

In nutshell, it can be argued that the solution to technological improvements having positive employment effects, via productivity gains and scale expansion, lies in greater global trade and investment integration. Insights from the paper also highlight the need for strengthening labour productivity and wage rate linkages to simultaneously address the supply and demand side effects of technology on economic growth. In other words, the paper argues for building on the new growth theories as other theoretical strands provide limited insights into the issues under consideration.

Two limitations of such a study need to be mentioned. Firstly, the observations need to be interpreted with caution as the analysis has been carried out at a fairly aggregate level. A more detailed sectoral analysis would perhaps present a clearer and more conclusive picture of the implications of technological changes for the labour market consequences, work on which is already underway. Second, the analysis must be extended further, by categorizing the labour force in terms of their skill-levels. Such an exercise would be closer to reality and perhaps provide newer insights into the issues.

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Table 1
Relationship among Labour intensity, Labour productivity and Scale of Operation: Select Developing Countries

$$LI = \alpha + \beta_1 LP + \beta_2 SO + \mu$$

	Countries	Constant (α)	Coefficient of Labour Productivity (β_1)	Coefficient of Scale of Operation (β_2)	R^2
NIE-I	**S. Korea**	0.20 (17.55)	-0.00002 (-7.27)	0.0003 (6.28)	0.74
NIEs-II	**Indonesia**	0.08 (10.39)	-0.0001 (-2.07)	0.0001 (0.61)	0.34
	Malaysia	0.11 (10.81)	-0.01 (-0.67)	0.03 (0.30)	0.19
	Thailand	0.09 (9.76)	-0.002 (-3.11)	0.004 (2.77)	0.33
South Asia	**Bangladesh**	0.15 (10.40)	-0.02 (-4.82)	0.05 (3.94)	0.52
	India	0.13 (10.42)	-0.03 (-4.12)	0.08 (3.84)	0.49
	Pakistan	0.13 (16.40)	-0.01 (-5.66)	0.01 (4.97)	0.65
	Sri Lanka	0.09 (9.08)	-0.001 (-1.35)	-0.001 (-0.39)	0.20

Source: Based on data from UNIDO, *International Yearbook of Industrial Statistics*, various years.
Notes: (i) NIE-I represents first-tier NIE and NIEs-II represents second-tier NIEs. (ii) Values in parentheses are t-statistic. (iii) Labour Productivity = Output per employee, (v) Scale of Operation = Output per establishment

Table 2
Relationship among Labour intensity, Labour productivity and Scale of Operation: Select Developed Countries (EU-15)

$$LI = \alpha + \beta_1 LP + \beta_2 SO + \mu$$

Country	Constant (α)	Coefficient of Labour Productivity (β_1)	Coefficient of Scale of Operation (β_2)	R^2
Austria	2.02 (1.56)	-0.41 (-7.00)	0.04 (2.89)	0.62
Belgium	1.88 (3.90)	-0.44 (-0.60)	-0.29 (-0.88)	0.49
Denmark	6.31 (3.11)	-12.35 (-3.02)	5.00 (2.13)	0.26
Finland	2.29 (5.73)	-0.64 (-6.76)	0.05 (0.97)	0.50
France	2.54 (0.97)	-0.70 (-8.97)	-0.02 (-0.29)	0.72
Germany	3.81 (1.12)	-0.82 (-9.55)	0.22 (4.28)	0.58
Greece	6.30 (1.64)	-0.67 (-5.18)	0.45 (3.71)	0.29
Ireland	2.98 (0.051)	-0.75 (-7.69)	0.10 (2.79)	0.74
Italy	4.77 (3.42)	-1.22 (-9.31)	-0.09 (-0.75)	0.65
Luxembourg	1.85 (3.03)	-0.67 (-3.72)	0.03 (0.47)	0.76
Netherlands	2.06 (1.59)	-0.07 (-0.53)	-0.16 (-2.09)	0.36
Portugal	1.17 (0.40)	-1.50 (-4.37)	0.26 (1.45)	0.31
Spain	3.00 (4.10)	-0.57 (-8.58)	0.01 (0.53)	0.74
Sweden	3.87 (2.77)	-0.61 (-7.69)	0.03 (0.31)	0.67
United Kingdom	2.06 (5.03)	-0.23 (-4.27)	-0.20 (-4.85)	0.52

Source: Same as in Table 1.
Notes: (i) LI = Labour Intensity, LP = Labour Productivity, SO = Scale of Operation.
(ii) Values in parentheses are t-statistic.

Table 3
Labour Productivity and Wage Rate Linkages: Select Developing Countries

Equation: $L_2 = \alpha + \beta L_1 + \mu$

	Country	Constant (α)	β	R^2
NIE-I	**S. Korea**	3.74 (0.98)	0.25 (8.94)	0.75
NIEs-II	**Indonesia**	0.19 (0.01)	0.43 (12.53)	0.86
	Malaysia	-2.67 (-1.92)	0.39 (11.46)	0.83
	Thailand	-1.59 (-1.44)	0.46 (7.05)	0.66
South Asia	**Bangladesh**	-2.04 (-1.79)	0.46 (3.61)	0.33
	India	-2.12 (-1.99)	0.41 (6.05)	0.58
	Pakistan	-1.54 (-1.49)	0.25 (4.34)	0.42
	Sri Lanka	-1.70 (-1.21)	0.13 (1.84)	0.12

Source: Same as Table 1.
Notes: (i) Values in parentheses are t-statistic. (ii)L_1 = Labour Productivity (iii) L_2 = Wage Rate

Table 4
Labour Productivity and Wage Rate Linkages: Select Developed Countries (EU-15)

Equation: $L_2 = \alpha + \beta L_1 + \mu$

Country	Constant (α)	β	R^2
Austria	1.21 (3.51)	0.46 (2.51)	0.41
Finland	0.03 (2.22)	0.88 (2.99)	0.55
Germany	0.26 (1.03)	0.25 (2.21)	0.30
Greece	1.87 (9.91)	0.28 (0.88)	0.01
Ireland	0.37 (3.36)	0.77 (2.93)	0.65
Italy	0.94 (3.31)	0.10 (0.78)	0.01
Luxembourg	1.49 (7.66)	0.52 (1.38)	0.15
Portugal	1.39 (2.00)	0.38 (2.71)	0.56
Spain	1.61 (3.77)	0.44 (3.74)	0.05
Sweden	1.71 (9.00)	0.35 (2.58)	0.44
United Kingdom	1.32 (4.46)	0.58 (3.85)	0.60
France	1.71 (3.95)	0.35 (1.58)	0.05
Netherlands	1.47 (5.39)	0.68 (2.83)	0.40
Belgium	4.38 (7.09)	-0.29 (-0.86)	0.08
Denmark	2.10 (3.81)	-0.02 (-0.04)	0.0001

Source: Same as in Table 1.
Notes: (i) Values in parentheses are t-statistic. (ii) L_1 = Labour Productivity (iii) L_2 = Wage Rate