TECHNOLOGY, PRODUCTIVITY AND EMPLOYMENT

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Analytical Frame

Innovation is endemic to non-input driven economic growth which is designated as total factor productivity growth (TFPG), after controlling for returns to scale. TFPG in turn is a combination of technological progress and change in technical efficiency; an important determinant of total factor productivity growth, particularly the technological progress component, is linked to innovation. Endogenous growth models urge that research and development (R&D) expenditures taken as a broad proxy for innovative moves contribute directly to firms' productivity enhancement, and indirectly through their industry-wide spill-over effects (see Grossman and Helpman, 1990; Romer; 1986). However, the effect of innovation on employment is an important concern. Whether innovation tends to reduce employment or it can be conducive to employment growth is a pertinent issue. If innovation means lesser utilization of all the factors of production for the same level of output, then naturally it tends to reduce employment per unit of output as well. But, if innovation reduces the utilization of some of the factors of production and not labour, then both innovation and employment can go hand in hand. In support of this view it may be argued that output growth is faster than the growth of some of the inputs such as capital but not labour because the labour contracts may involve rigidity. Labour might have been hired on a long term basis, which can be treated as a sunk cost (fixed or variable) - a retrospective cost that has already been incurred and cannot be recovered. Besides, the operation of the new technology is not necessarily automated which involves labour displacement.

A related point is also of great interest. Even if innovation leads to lesser utilization of all the factors (including labour) for a given level of output, the rise in the quantum of production certainly contributes to employment generation, i.e., the scale effect. Modernization of technology may lead to its large scale application in various sectors of the economy and hence, the quantum of production and employment both may increase simultaneously even when the new technology gets more capital intensive. These issues of employment increase at the aggregate level due to wider application of the advanced technology prompted by the profit motive are certainly of great relevance, particularly in the context of the developing economies confronted with the compulsion of maximizing growth and generating employment opportunities for the vast supplies of labour.

However, from another angle there can be a negative effect of innovation on employment. Since technological innovations largely take place in developed countries, they are made to suit these economies and their factor endowments. Incidentally, these countries are primarily labour scarce and thus, the new technology tends to become increasingly labour saving (Pack and Todaro, 1969). In other words, the developed countries are faced with a severe shortage of labour ready to pursue mechanical jobs, and thus, the innovations relating to technical progress are usually pursued with an objective of reduction in labour requirement in the production process. So technical progress and rising capital intensity proceed synonymously, which do not conflict with the labour market situation in the developed countries[2]. However, with import liberalization if the developing countries import this sort of technology at a cheaper cost, it restricts their employment growth particularly in the high productivity formal sector. Thus, the labor-saving technical change is a definite disadvantage to

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[2] Different mechanisms of technological change and effects on jobs emerge in the work of Bogliacino and Pianta (2010).

developing economies (Kelley, Williamson and Cheetham, 1972. Though UNIDO (2005) argues that it is still cheaper for a latecomer to buy the technology already invented by others than to re-invent the wheel, there can be serious implications in terms of employment loss. Chakravarty (1987) noted that with imports of capital goods on a significant scale, domestic costs of production are unlikely to come down since developing countries might be importing expensive capital goods. Further, imports of capital goods can act as substitutes for domestic production of capital goods, imposing a social cost in the form of unutilized capacity making the domestic firms operate at high unit cost of production (Chandrasekhar, 1992).

The adoption and adaptation of these international technologies are indeed costly because of tacit knowledge and circumstantial sensitivity of technology (Evenson and Westphal 1995). Unless an importing country has significant technological capability, it cannot fully utilize the imported technology*.* Besides, imported technology may require more skilled than unskilled workers while developing countries are usually have an abundant supply of the latter type. Acemoglu and Zilibotti (2001) argue that due to the difference in skill scarcity, technology in developed countries tends to be skill intensive and is inappropriate for developing countries. Thus the potential productivity of imported technology cannot be realized in developing countries.

In the backdrop of these views the present paper proposes to assess the impact of TE and TFPG on labour absorption. It is organized as follows: section 2 reviews of some of the studies on innovation and employment and section 3 presents the empirical analysis. Section 4 summarises the major findings. The database of the study is drawn from various companies across industry groups.

Review of Studies

A thorough review of literature both on theoretical and empirical aspects needs to be pursued before turning to the empirical analysis. The combination of capital, labor and other factors of production is optimized in the process of innovation and its impact on total employment and employment structure is cyclical. In the initial stages, total employment grows sluggishly or even declines, while employment structure does not change significantly; at a later stage, there are rapid increases in total employment and marked changes in employment structure; and in the final stage of innovation, changes both in total employment and employment structure gradually diminish until the next innovation comes through (Guangrong and Yuanyuan, 2009).

If the new technology enhances productivity as well as promotes employment, the choice is clear. Such a possibility, though empirically difficult to materialize, exists at least theoretically. For example, technological progress brings in upward shift in the production frontier, which would mean higher levels of output for the given levels of inputs. In such a situation if the new technology becomes labour intensive, the rise in value added and employment both will be witnessed. However, the value added growth will be more than the rise in employment, and hence, labour productivity can actually shoot up[3]. Conversely, the new technology can dampen employment and improve productivity by adopting capital-deepening process.

Negative Relation between Innovation and Employment

Choi, Yub and Jin (2002) analyzed the implications of Hicks-neutral technical progress for a small Harris-Todaro economy with variable returns to scale. The analysis demonstrates that the welfare

[3] However, when output is fixed, the shift in technology from being capital intensive to labour intensive would result in deterioration in labour productivity.

effects of technical progress consist of three components, i.e., the primary growth effect, the returns-to-scale effect and the employment effect. This type of decomposition is indeed useful as it deciphers the effects of technical progress into various components. Besides, the study works out the possibilities under non-constant returns to scale which is a much stronger possibility in the real world than a constant returns to scale situation. Under constant returns to scale the possibility of poverty-aggravation may not exist and one may conclude that technical progress will be beneficial. But with the introduction of non-constant returns to scale, technical progress can lead to the returns-to-scale effect, which can be of any sign, and the sum of the primary growth effect and the employment effect again can be of any sign. In other words, growth without employment generation is possible as technical progress tends to reduce labour absorption.

Technical progress and rising capital intensity in the literature are almost synonymous. On the other hand, innovation in the line of labour intensive technical progress is a difficult proposition. The capital intensive technical change also has important implications for rates of industrialization and capital accumulation even when the economies, particularly in the developing world, are characterized by a dual economic structure. Kelley, Williamson and Cheetham (1972) noted that increases in the bias may tend to inhibit the rate of industrialization and reduce the rate of capital accumulation without appreciable changes in per capita GNP growth. Related to these results is the extent to which labour absorption in the industrial sector is affected. The study observed an important retarding influence that accumulates over time. It questions the wisdom of introducing labour saving technology in the industrial sector in order to enhance per capita growth. The authors rather noted that per capita income is mostly insensitive to the technological bias introduced in the industrial sector of the developing countries. Hence, the outcome is neither an increase in per capital income nor a rise in employment in the industrial sector in response to adoption of capital intensive technology.

In fact, Mureithi (1974) elucidates this point with great lucidity. The rising capital-labour ratio means that each job creation becomes more capital-expensive. Of course it must not be supposed that rising capital intensity is bad per se as a large part of the capital formation could be devoted to the building of infrastructure like roads, public works, communications, etc.

Positive Association between Innovation and Employment

In addition, as Mureithi (1974) argues, it is pertinent to realize that production actually takes place in stages: l) material handling, 2) material processing, 3) material handling among processes, 4) packaging, 5) storage of the finished products. Of the five stages, only the second, i.e., the central processing, is capital intensive because at this stage the finer precision of temperature, pressure, ingredients combination, etc, is important. But there are many other stages where factor substitutability is technically possible and thus the entrepreneurs have a choice to select the technology. The desirability of a technology has to be judged not merely by its scientific or technical sophistication, but rather by its appropriateness in the context of the society in which it will be used. It requires innovative ideas to reduce the labour-saving elements of a technology while maintaining or improving quality and efficiency. Even after accounting for the fact that there could be stages where capital intensive technology is absolutely necessary, innovation and employment can move in a positive direction in many other stages which then can offset the negative association between technology and employment as conceived in certain specific stages.

The “compensation theory” as Vivarelli (2011, 2013) points out, argues that technological unemployment is a temporary phenomenon. The labour saving effects of technology can be offset through: "(1) additional employment in the capital goods sector where new machines are being produced, (2) decreases in prices resulting from lower production costs on account of technological innovations, (3) new investments made using extra profits due to technological change, (4) decreases in wages resulting from price adjustment mechanisms and leading to higher levels of employment, (5) increases in income resulting from redistribution of gains from innovation, and (6) new products created using new technologies" (Vivarelli, 2013)[4].

Another interesting point in relation to the preference for new technology is as follows (James, 1993). If new technology is not adopted it may affect the quality of products as well as exports, resulting in employment loss. On the other hand, adoption of new technology which is capital intensive in nature can cause employment to fall. Hence, one has to compare between employment loss due to drop in exports prompted by the traditional labour intensive technology and employment loss due to adoption of capital intensive technology to assess which one is greater in magnitude. Further, the speed of production, product flexibility and location specific factors need to be considered in assessing the total effect of technology on employment. If certain products are manufactured in the low cost countries labour intensive technology can still be pursued. Hence, the factor price ratio is an important determinant of technology choice and decision about location of production base, which eventually impact on employment. The idea of enlarging the production base across the globe is embedded in the study by James (1993). While the low labour cost countries can specialize in the production of certain goods or certain components of the composite goods using the labour intensive methods, the developed countries may specialize in certain other components that require very high levels of capital and skill. Thus, the newer and innovative ways would mean that technical progress would not only suit the labour market situation of the developing and the developed countries both but also bring in a positive relationship between innovation and employment at large.

Bogliacino (2014) using company data from R&D Scoreboard for Europe analyzed the microeconomic relationship between innovation and employment. He observed the prevalence of scale effect for a given R&D intensity generating an increasing relationship between total turnover and employment. Bogliacino and Vivarelli (2012) using database of 25 manufacturing and service sectors across 16 European countries and applying GMM-SYS panel estimations of a demand-for-labour equation augmented with technology noted that R&D expenditures have a job-creating effect. Bogliacino, Piva and Vivarelli (2012) tested the job creation effect of business R&D applying the dynamic LSDVC estimator to a longitudinal database of around 677 European companies and found it to be positive in services and high-tech manufacturing though not in traditional sectors. Using the data from the three surveys on Italian manufacturing firms Hall, Lotti and Mairesse (2008) found no evidence of significant employment displacement effects arising from process innovation. Though Harrison et. al. (2014) using comparable firm-level data from France, Germany, Spain and the UK detected large displacement effects induced by productivity growth in the production of old products, the effects related to product innovations were seen to be strong enough to more than compensate these displacement effects.

A positive relationship between innovation and employment has been conceptualized in a novel way by Saviotti and Pyka (2004). Interpreting economic development as synonym for new goods, services or sectors they view it as a result of increasingly systematic use of innovation. It is quite natural that as the old product or services matures employability declines. Thus, to improve the

[4] Also see Vivarelli (1995) and Pianta (2005).

level of employment in a continuous manner, innovation has to go on and new goods and services have to be produced. In this sense innovation and employment can go hand in hand. The ability to reap variety is a manifestation of economic development, which in turn can create employment steadily. Also, on the productivity front its growth may not take place indefinitely implying upper bounds on sectoral productivity growth. In order to augment the productivity growth at the country level efforts have to be pursued to create new sectors. On the whole, the possibility of a positive relationship between innovation, employment and growth is very much comprehensible.

Innovation and Type of Labour

Next, one may pose the question in relation to product and process innovation. The interaction between economic integration, product and process innovation, and relative skill demand is an important aspect, which Braun (2008) analyses in a model of international oligopoly. Lowering of trade barriers increases the degree of foreign competition which may have effects on the incentives of firms to undertake R&D investment and also the firms' demand for skilled relative to unskilled workers. Increased competition following economic integration induces firms to bring down production costs by investing more aggressively in process R&D. At the same time, competitors expand their investments in product innovation in order to reduce the substitutability of their products. However, all this would require highly skilled human labour which can initiate newer ways of introducing cost efficient production processes and bring down the product differentials between the imported goods and the domestically produced goods. On the whole, economic integration and innovation are inter-linked resulting in an increase in the relative demand for skilled workers[5] and not the unskilled or semi-skilled variety of labour force which is in excess supply in most of the developing countries. Innovation and skill intensity usually go together – hence, even if innovation is not always labour displacing it benefits only those who are relatively in short supply. This tends to indicate that wage inequality is likely to increase in the process of innovation and increased trade.

On the empirical front Berman and Machin (2004) showed the skill-bias of technological change especially in middle-income countries. Pianta (2005) emphasizes that innovation-based growth and job creation may operate in drastically different ways during different phases of the cycle, implying that the employment dynamics are not affected by the same factors and in the same ways during the upswings and the downswings. Piva (2003) presents a critical comparison of the positive implications of technology transfers (such as positive spillovers, technological catching-up, growing complementarities with domestic firms) with the negative ones (displacement of workers, negative welfare implications, competitive effects with domestic firms). Also, the author considers the nature of transferred technologies (labour-saving and/or skill-bias, embodied or not embodied in capital), together with the different institutional 'absorptive capacities' and sectoral specializations of both middle-income and low-income developing countries.

Lee and Vivarelli (2006) suggest that import of capital goods may imply an increase in inequality via skill-biased technological change. Imports of capital goods, - embodying technological innovations - are important because of the role they play in contributing to capital upgrading and more generally to the economic growth of the developing countries. In fact, even without necessarily assuming that developed countries transfer their "best" technologies, transferred technologies are relatively skill-intensive, i.e. more skill-intensive than those in use domestically before trade and FDI liberalization. Thus openness – via technology – should imply a counter-effect to the SS theorem

[5] Vivarelli (2011) argues that innovation has a strong skill-bias.

prediction, namely an increase in the demand for skilled labour, an increase in wage dispersion and so an increase in income inequality.

Castellani and Zanfei (2006) present an in-depth theoretical and empirical analysis of the key issues underpinning the relationship between innovation and multinational companies. The authors argue that neither every foreign firm is a good source of externality nor every domestic firm is equally well placed to benefit from multinationals. Spillovers from multinationals differ according to the technological profiles, embedded-ness and linkage creation of both foreign and domestic firms. Hasan (2002) presented evidence from panel data on Indian manufacturing firms in favour of a significant effect of imported technology on productivity. In general the empirical literature on R&D, using cross-sectional data, reports strong evidence in favour of its positive effect on productivity while the time series estimates are less conclusive (Crespi and Pianta, 2006). Using data on 33 Indian manufacturing industries in India for the period, 1992 through 2001, Pandit and Siddharthan (2006) further showed that technology imports, through joint ventures and MNE participation, influence employment positively. They noted that employment growth, production of differentiated products, skill intensity of the work force and technological up-gradation go hand in hand. On the other hand, Mitra (2009) observed a decline in employment to value added ratio with a rise in manufacturing imports including technology.

However, the "compensation theory" as Vivarelli (2013) points out, argues that technological unemployment is a temporary phenomenon. The labour saving effects of technology can be offset through:

(1) additional employment in the capital goods sector where new machines are being produced,
(2) decreases in prices resulting from lower production costs on account of technological innovations,
(3) new investments made using extra profits due to technological change,
(4) decreases in wages resulting from price adjustment mechanisms and leading to higher levels of employment,
(5) increases in income resulting from redistribution of gains from innovation, and
(6) new products created using new technologies (Vivarelli, 2013).

Impact of TE/TFPG on Employment

Keeping in view the recent advancements in the literature employment to sales ratio perceived as a rough proxy for labour requirement per unit of output has been regressed on R&D to sales ratio, exports to sales ratio, imports to sales ratio, assets to sales ratio and efficiency (or TFPG). In an alternative specification employment to sales ratio has been replaced by log of employment, without changing the determinants[6]. This is pursued mainly to capture the view that labour per unit of real output (approximated by real sales) may not increase in response to R&D though the overall employment may[7]. The performance indicator is included to test if TFP growth, for example, results in higher output growth relative to input growth including labour or alternately, does not affect employment though reduces the use of other inputs.

[6] Wages are not considered because capital asset is included as a determinant. Since capital itself is a function of wage rental ratio multicollinearity and the problem of double counting would have emerged had we included wage rate in the function.

[7] If the rise in output is more than employment then labour per unit of output may decline in spite of an increase in overall employment.

In the equation which includes technical efficiency as one of the determinants the following three industry groups unravel a positive effect of R&D to sales ratio on employment: Engineering (Industrial Equipment), Household and Personal Products, Pharmaceutical and Drugs (Table 1). In the rest of the industries R&D to sales ratio remains insignificant. Technical efficiency shows a negative effect on employment to sales ratio in the case of Electronics Component and a positive effect in engineering (industrial equipments) and remains insignificant in the rest of the industries.

The ratio of exports to sales is significant with a positive coefficient in three industries and negative only in one. Similarly the imports to sales ratio show a significant value only in three industries and among them two are positive. Based on this it is difficult to generalize that trade contributes to employment generation. However, some of the labour intensive sectors like Consumer Durables (Domestic Appliances) and Household and Personal Products show a positive effect of both export to sales and import to sales on employment to sales. While higher exports lead to increased employment, imported inputs also tend to create employment, suggesting possibilities of complementary relationship between the imported inputs and skilled labour. Not any major improvement in results is obtained by redefining the dependent variable as log transformation of employment[8].

Table 1: Employment/Sales and R&D/Sales with TE Dependent variable: Employment/Sales

Industry	Model	R&D/ Sales	Export/ Sales	Import/ Sales	Asset/ Sales	TE	Constant	R^2 / Adj R^2	N
Consumer Durables-Domestic Appliances	OLS	-60.906 (-0.33)	5.501* (1.96)	35.87** (4.03)	1.452 (0.40)	0 .988 (0.15)	7.307 (1.61)	0.37	29
Consumer Durables-Electronics	OLS	309.098 (1.55)	-32.78** (-2.91)	3.074 (0.98)	-10.741 (-1.77)	21.641 (1.49)	2.868 (0.50)	0.70	18
Chemical	RE	30.674 (1.23)	-1.045 (-1.00)	-0.837 (-0.66)	1.856** (4.44)	1.002 (0.24)	3.063** (2.36)	0.07	186
Electric Equipment	RE	203.766 (1.22)	-1.135 (-0.22)	-0.448 (-0.05)	1.484 (0.81)	-31.656 (-1.14)	9.350** (2.86)	0.03	96
Electronics Component	OLS	31.550 (0.18)	32.149** (2.94)	19.948 (1.66)	0 .172 (0.64)	-83.524** (-3.53)	29.970** (4.19)	0.41	32
Engineering	RE	161.433 (0.49)	-1.057 (-0.19)	-2.679 (-0.42)	8.776** (3.37)	-21.047 (-1.22)	10.140** (2.68)	0.40	45
Engineering Construction	OLS	3968.547 (1.21)	-4299.38 (-1.45)	17.053 (0.82)	0 .687 (0.10)	-40.983 (-1.12)	40.997 (1.20)	0.36	7
Engineering – Industrial Equipments	OLS	1431.9** (2.62)	2.444 (0.31)	-91.238** (-3.37)	8.080** (3.57)	104.567** (2.88)	-28.425** (-2.10)	0.68	31
Household & Personal Products	RE	374.736** (3.00)	18.092** (2.13)	41.933** (2.71)	2.105 (1.10)	-27.171 (-1.31)	14.116** (2.31)	0.02	46
Leather	RE	1799.993 (0.92)	15.840 (1.62)	-30.546 (-0.93)	-5.998 (-0.33)	-29.798 (-1.31)	27.965 (1.63)	0.31	26
Pharmaceuticals & Drugs	FE	56.84** (5.53)	-3.520 (-1.37)	1.738 (0.42)	8.70** (318.97)	-41.86 (-1.45)	11.692** (3.33)	0.97	499

Note: Figure in parenthesis are t- values for FE model and OLS and z-value for RE model. ** and * denote 5% and 10% level of significance, respectively. FE denotes fixed effect model: RE denotes random effect model: OLS denotes ordinary least square. Adj. R^2 is calculated only for OLS.

As we replace technical efficiency by TFPG in the equation for employment to real sales ratio, the results relating to R&D/Sales ratio remain unchanged except for Electronics Component which now turns out to be negative and significant (Table 2). TFPG itself is significant only in two industries

[8] Results not reported.

with a negative coefficient, implying higher growth in output relative to input growth. Electronics Component and Household and Personal Products show a positive effect of both exports and imports. Even after changing the dependent variable to log of employment both these industries continue to indicate the positive effect of trade. Also, after changing the dependent variable to log of employment Electronics Component, Engineering (Industrial Equipment) and Leather show a positive effect of R&D to sales on employment with no negative effect in any of the other industries[9].

On the whole, the R&D/sales ratio is not significant in a number of industries; however, the cases of positive impact are noteworthy.

Table 2: Employment/Sales and R&D/Sales with TFPG Dependent Variable: Employment/Sales

Industry	Model	R&D/ Sales	Export/ Sales	Import/ Sales	Asset/ Sales	TFPG	Constant	R^2 / Adj R^2	N
Consumer Durables-Domestic Appliances	OLS	-49.604 (-0.26)	5.494 (1.68)	35.483** (4.04)	1.390 (0.38)	1.541 (0.05)	7.933** (4.69)	0.37	29
Consumer Durables-Electronics	OLS	119.961 (0.50)	-32.922* (-2.72)	-1.491 (-0.69)	-3.828 (-0.42)	-1.265 (-1.10)	10.801** (7.99)	0.67	18
Chemical	FE	25.810 (0.98)	-0.244 (-0.20)	-0.115 (-0.09)	1.964** (4.43)	-1.069 (-0.24)	3.216** (6.56)	0.03	186
Electric Equipment	RE	171.269 (1.03)	0.343 (0.07)	-3.024 (-0.37)	2.482 (1.45)	4.331 (0.37)	6.066** (2.76)	0.005	96
Electronics Component	RE	-425.871* (-1.92)	14.137* (1.94)	22.107** (2.24)	1.062** (3.22)	-49.693** (-2.88)	5.626** (2.79)	0.47	30
Engineering	RE	127.925 (0.38)	-1.050 (-0.19)	-5.082 (-0.78)	9.592** (3.92)	-14.093 (-1.08)	7.162** (2.73)	0.28	45
Engineering Construction	OLS	-1633.149 (-0.24)	1167.04 (0.27)	32.055 (1.49)	7.146 (1.05)	28.362 (0.69)	1.882 (0.64)	0.02	7
Engineering – Industrial Equipments	OLS	2076.12** (3.56)	10.245 (1.16)	-76.600** (-2.45)	4.745* (1.74)	-5.985 (-0.08)	8.787* (1.79)	0.58	31
Household & Personal Products	RE	403.708** (2.88)	19.15** (2.07)	38.48** (2.23)	2.055 (1.01)	-9.267 (-0.81)	6.910** (3.48)	0.02	46
Leather	OLS	1065.961 (0.65)	22.45** (2.64)	-28.044 (-1.04)	9.830 (0.62)	-128.113** (-3.22)	5.005 (0.44)	0.38	26
Pharmaceuticals & Drugs	RE	58.454** (5.93)	-5.212** (-2.29)	0.099 (0.03)	8.701** (323.13)	0.970 (0.10)	7.278** (5.09)	0.98	499

Note: Figure in parenthesis are t- values for FE model and OLS and z-value for RE model. ** and * denote 5% and 10% level of significance, respectively. FE denotes fixed effect model: RE denotes random effect model: OLS denotes ordinary least square. Adj. R^2 is calculated only for OLS.

Conclusion

In this study we assessed the impact of performance index (measured in terms of TFPG and technical efficiency) and research and development expenditure on employment. As regards TFPG or TE, findings are not indicative of any major decline in employment except in one or two industries. However, there is no major evidence in favour of an increase in the employment either. Turning to R&D expenditure, three industries showed a positive effect on employment to sales ratio and it is only one industry for which a negative and significant coefficient is estimated. Hence, it may be erroneous to conclude that innovation index or innovation expenditure results in loss of employment. Production process comprises a number of phases some of which could be labour saving while some others may be generating additional employment. Though no large scale evidence is available in favour of net

[9] Results not shown.

employment gains, labour utilization rate is also not seen to be a negative function of innovation. Domestic innovation may be pursued to develop appropriate technology and the employment potential can be explored in a number of areas. How domestic innovation can be encouraged and how joint ventures in this context can be pursued are some of the critical issues which can be addressed through effective policy making.

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