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An Analysis of Technology Adoption by Export-oriented Manufacturers in Pakistan

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1. INTRODUCTION

The last two decades have witnessed a remarkable spread of technology in all spheres of economic activity. The change has been so rapid that firms are finding it difficult to keep pace with ever-changing market situations. The issue of technology adoption is particularly relevant for export-oriented manufacturers who face tough competition in international markets and must maintain a competitive edge by adopting latest product and process technologies to meet the requirements of upscale global markets. It is generally believed that Pakistani firms have lagged behind their competitors in international markets in terms of technological advancement and consequently Pakistan's exports continue to remain concentrated in low value-added and low quality product segments. However, the question of technology adoption by export-oriented manufacturers has received little attention in the empirical literature. This study is an attempt to explore the determinants of technology adoption by export-oriented manufacturing firms in Pakistan based on a survey of such firms in four major export categories including textiles and apparel, leather and leather products, agro-food processing and fisheries.

According to Woodside and Biemens (2005), the term technology adoption refers to the decision-making process of an individual firm.[1] Technology adoption is a complex phenomenon and depends in large measure on firm characteristics and the economic environment under which the firms operate. This study focuses on firm characteristics that are believed to influence the probability of firms' decisions whether to invest in technology or not. The data relating to technology adoption is seldom available in a developing country like Pakistan. However the survey conducted by Pakistan Institute of Development Economics in collaboration with United Nations Industrial Development Organisation (UNIDO) contains a binary response question[2] which has been used as a

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[1]Technology adoption is distinct from technology diffusion. Sarkar (1998) defines technology diffusion as a "mechanism that spreads successful varieties of products and processes through economic structure and displaces wholly or partly the existing inferior varieties". See also Rogers (1995) for a similar distinction.

[2]The statement of the question is: "Please indicate whether or not you have made investment in the past three years in issues such as process technology, packaging, product design, that were necessary to meet specific client/market requirements."

dependent variable in a Logit model for estimation of probabilities of firms' decision to invest in technology. The rest of the paper is organised as follows: Section 2 describes the data and sets out the methodology. Section 3 provides a discussion of the empirical results whereas Section 4 contains conclusions and policy recommendations.

2. DATA AND METHODOLOGY

This study is based on a survey of export-oriented firms conducted by the Pakistan Institute of Development Economics (PIDE) in collaboration with the United Nations Industrial Development Organisation. The sample covers 157 exporting firms in four major sectors viz. textiles, leather, agro-food processing and fisheries located in Sindh and Punjab provinces. [3] Various sub-sectors are covered under each of the major export segment: in the textiles, yarn, fabrics, knitwear, garments and bed sheets and towels; in leather, tanning, footwear and leather products; in agro-food processing, horticulture products, and rice; and the fisheries comprise various types of fish processing enterprises and fish exporters. [4]

Various models have been used in the literature to model firms' decisions pertaining to technology adoption. In this paper, we employ the rank model of technology adoption.[5] This model is based on the observation that the decision to adopt a particular technology is a choice made by a particular firm that is influenced by a range of firm's characteristics including the age and size of the enterprise, volume of sales, location, and type of ownership. These characteristics are assumed to determine a threshold level and the adoption of technology is likely to occur if this threshold is crossed. The rank model of technology adoption has a sound theoretical basis in that it is built upon the profit maximising behaviour of a firm. The empirical implementation of the rank model is carried out in terms of a binary choice model.

The choice of technology adoption is a discrete choice. Firms either invest or do not invest in new technologies. Due to this categorical nature of dependent variable, the ordinary least squares method will not produce the best linear unbiased estimator i.e., OLS estimate are biased and inefficient. This situation calls for the use of one of the binary dependent variable techniques. In the literature two most commonly used techniques are Logit and Probit models. The basic difference between these two techniques lies in the assumption about the distribution of the error term. In the Logit model, errors are assumed to follow the logistic distribution, whereas in the Probit model errors are assumed to follow the standard normal distribution.[6] In this paper we use the Logit estimation technique.

This function has two useful characteristics in the present context. First, the value of the function is limited between 0 and 1, as necessary for a probability model. Second, the distribution of the function follows an S-shaped curve, exhibiting a typical technology adoption pattern (Figure 1).

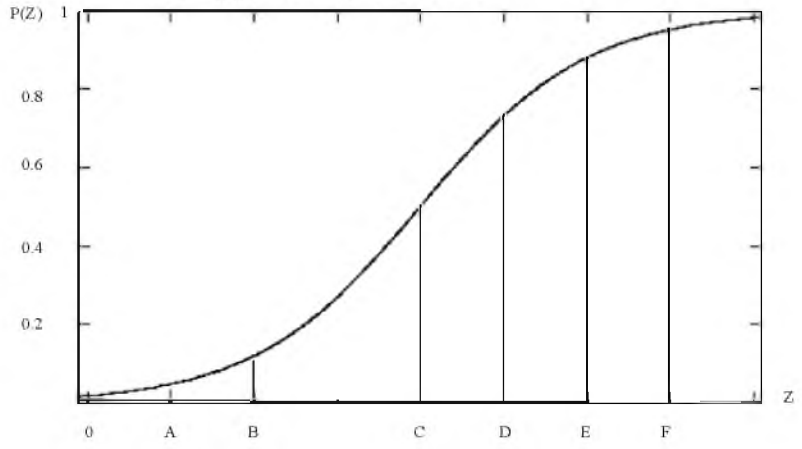
[3]The sample was selected from a universe of 1300 exporters using the stratified sampling approach.

[4]See PIDE (2007) for further details.

[5]The rank model was first propounded by David (1969) and was further developed by David (1975); Davies (1979); and Ireland and Stoneman (1986). The model and its variants have been extensively used in studies of technology adoption at the firm level; see for instance David and Olsen (1984); Bartoloni and Baussola (2001); Fariaa, *et al.* (2002) and Parhi (2008). For a detailed survey of this literature [see Sarkar (1998) and Geroski (2000)].

[6]The choice between the Logit and Probit models is largely one of convenience and convention, since the substantive results are generally indistinguishable [Long (1997), p. 83].

Fig. 1. The Logistic Function, with *z* on the Horizontal Axis and P(z) on the Vertical Axis



The impact of an event on the probability depends on the initial probability of the event. If the Z moves from point A to point B, the probability of the event increases by a very small amount. However, a movement of equal magnitude from point C to point D increases the probability of the event by a relatively larger amount. Again the change in the value of the probability is small as Z moves from point E to F. This is a typical behaviour of technology adoption; at initial stages adoption occurs at a slow pace, gradually it picks up momentum, and slows down again as adoption process approaches a saturation point.

The logistic function is given by:

$$P_i = e^z /(1+e^z)$$

Where P_i is the probability of a binary outcome (adoption or non-adoption of new technology by the firm i, and $Z = \beta X$, where vector X represents firms' characteristics, and β is a vector of coefficients. The unknown parameters can be estimated by Maximum Likelihood Method. The natural log of odds ratios is given by:

$$Z_i = \ln[P_i / (1 - P_i)]$$

Since these probabilities are not directly observable, we proxy these by a binary variable y_i which takes a value of 1 if the i^{th} firm makes an investment in new technology and 0 otherwise. Using y_i as a dependent variable we estimate the following model:

$$y_i = \beta_0 + \beta_1 lnAge_i + \beta_2 Dsize_i + \beta_3 Location_i + \beta_4 lnSales_i + \beta_5 Cert_i + \beta_6 Own_i + v_i$$

Where

Age = Age of firm in years.

Dsize = Dummy variable with a value of 1 for large sized enterprises and 0 otherwise.

Location = Dummy variable taking a value of 1 if the firm is located in Karachi and 0 otherwise.

Sales = Sales in US$.
Certi = Dummy variable taking a value of 1 if the firm is certified and 0 otherwise.
Own = Dummy variable taking a value of 1 if the firm is domestically owned and 0 otherwise.

The age of the firm can affect the probability of investment in new technology in two ways. On the one hand, older firms that are more experienced and are better cognizant of the market opportunities and requirements could be more inclined to invest in new technology to maintain their competitive strengths acquired over a longer period of time. Also, older firms may in fact need to invest in new technology to replace their older machinery and equipment. One may, however, argue that newer firms having a modern outlook may be more likely to invest in new technology. The empirical evidence in the literature is mixed: Parhi (2008) finds a positive effect of age on technology adoption whereas Fariaa, *et al.* (2002) report a negative relationship between firms' age and probability of technology adoption.

Firm size can also influence a firm's decision to adopt new technology. The theoretical relationship between firm size and probability of investing in new technology is ambiguous. On the other hand, there are many reasons to expect positive relationship between firm size and investment. Large firms enjoy economies of scale in production, have a relatively higher capacity for taking risks, and have better financial positions all of which contribute to higher probability of investment on new technology. On the other hand, smaller firms may be more inclined to invest in new technology because of their desire to establish a toehold in the market and to enhance their scale based on newer technology. Empirical studies on the role of firm size in technology adoption find mixed evidence: Bartoloni and Baussola (2001) find positive relationship between firm size and technology adoption, whereas other studies have shown a higher probability of technology adoption by smaller firms [e.g. Oster (1982)].

Spatial clustering of economic activity and its role in interactive learning processes is important in technology adoption. The new literature on economic geography explicitly incorporates the role of geographical location in economic development process.[7] Positive externalities of such location include "cluster development" which leads to establishment of networks for dissemination of information so that 'best practices' in one cluster can foster demonstration effect in others. To capture such advantages, we use Location as a dummy variable which takes a value of 1 if the firm is located in Karachi—the city being the biggest commercial hub in Pakistan and still the only major port is believed to offer such geographical advantages. Fariaa, *et al.* (2002) find that firms located in industrialised districts have an 8 percent greater probability of adopting technology than those located in poor regions. However there are some negative externalities like congestion which may divert investment away from such a location. Sign and significance of this variable will reflect the net effect of these positive and negative externalities.

The firm's level of sales is likely to positively affect the probability of investment in new technology. Firms with larger sales have a better capacity as well as better motivation to invest in new technology to retain their market share through improving product and process technologies. Hence we expect this variable to have a positive sign.

[7] See, for instance, Krugman (1995).

Recent years have witnessed a growing demand from buyers for certification of conformity with standards and technical regulations.[8] The emerging trade environment under the umbrella of the World Trade Organisation (WTO) also calls for adherence to standards and norms such as quality certification as well as certification of conformity with health, labour, and environment standards. Such certifications demonstrate compliance with product safety and quality and manufacturers having such certifications are expected to perform better in export markets. Export-oriented firms that have obtained product and process certifications may be better inclined to upgrade their technology owing to their awareness of the benefits of new product and process technologies. We, therefore, expect that firms that are certified are more likely to invest in new technology and hence this variable is expected to have a positive sign in the Logit regression.

Ownership is also expected to play an important role in influencing a firm's decision to adopt new technology. We argue that domestic-owned firms are more likely to adopt new technology as compared with foreign-owned firms not least because of the technology gap they face and their drive to catch up with their foreign-owned counterparts. The foreign-owned firms, on the other hand, may be less likely to invest in new technology owing to their better technological base as compared with domestic-owned firms. Hence odds are in favour of domestic ownership having a higher probability of technology adoption.

3. MODEL ESTIMATION

The specified model has been estimated as a Logit regression[9] (Table 1). The null hypothesis that all the slope coefficients are simultaneously equal to zero is tested in terms of the likelihood ratio (LR) statistic. Given the null hypothesis, the LR statistic follows the χ^2 distribution with degrees of freedom equal to the number of explanatory variables. The results indicate that the null hypothesis is rejected. McFadden R-squared turns out to be about 0.32. However, as the theory suggests, in binary dependent models goodness of fit is of secondary importance. What actually matters is the expected signs of the coefficients and their statistical and/or practical significance.

Table 1

Results of Logit Regression Model

Dependent Variable: Yi Method: ML - Binary Logit				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	–3.67	1.96	–1.87	0.06
LAGE	–0.73	0.38	–1.94	0.05
DSIZE	1.75	0.67	2.60	0.01
LOCATION	0.66	0.61	1.09	0.28
LSALES	0.53	0.21	2.55	0.01
CERT	1.14	0.64	1.78	0.08
OWNERSHIP	1.44	0.85	1.69	0.09
LR statistic (6 df)	36.29	McFadden R-squared		0.32
Probability(LR stat)	0.00			

[8]Standards of certification are ISO9000, ISO14000, HACCP, SA8000, OHSAS, EUREPGAP, and Traceability.

[9]A Probit model has also been estimated, but the results are very similar (see Appendix).

The variable 'age' has a negative and significant coefficient implying that relatively new entrants are more likely to invest in new technology whereas the older firms are less inclined to invest in new technology. As expected, the coefficient of 'sales' is positive and significant, indicating that firms with large sales volumes have a higher probability to invest in new technology due to their better capacity to undertake such investments. This is because firms with large sales volumes. The dummy variable for firm size also turns out to be positive and significant showing that larger firms have a higher likelihood of investment in new technology to enhance economies of scale and achieve technological efficiency.

The coefficient of the dummy variable for certification is significant with a positive sign implying that being certified to international quality standards increases the probability of a firm's technology adoption. Firms that have obtained product and process standards have a better awareness about the benefits of new technology in terms of product quality and process efficiency. Hence such firms have a better likelihood of investing in new technology to maintain their competitive strengths. The location dummy turns out to be positive but insignificant, implying that clustering and other locational advantages do not significantly affect the firm's likelihood of investing in new technology.

The dummy variable for ownership has a positive and significant coefficient implying that domestically-owned firms are more likely to invest in new technology. As argued earlier, domestic firms may have a greater need for new technology as compared with foreign-owned firms and hence their probability of investing in new technology is higher. Alternatively, this result also implies that foreign-owned firms are less likely to invest in new technology. Mansfield (1994) argues that foreign-owned firms may not be inclined towards investing in new technology in developing countries as they are more concerned with their intellectual property rights and lax enforcement of intellectual property rights in developing countries acts as a potential deterrent to investment in new technology by foreign firms.

In the Logit regression, the marginal effects provide a good approximation to the magnitude of change in the dependent variable due to a change in the independent variable (Table 2). The predicted probability of a firm investing in new technology is 0.87 for large, certified and domestically-owned firms, evaluated at average values of

Table 2

Marginal Effects of the Logit Regression

Marginal effects after logit y = Pr(Investment) (predict) = 0 .87					
Variable	dy/dx	Std. Err.	z	P>|z|	X
Lage	–0.08	0.04	–2.06	0.04	2.90
DSize*	0.24	0.11	2.28	0.02	0.64
Location*	0.08	0.07	1.08	0.28	0.50
lsales	0.06	0.02	2.61	0.01	7.87
Cert*	0.16	0.11	1.49	0.14	0.78
Own*	0.23	0.17	1.38	0.17	0.85

(*) dy/dx is for discrete change of dummy variable from 0 to 1.

firm's age and volume of sales. An increase of one year in firm's age reduces the predicted probability of investing in new technology by 8 percent, holding other independent variables constant at the mean values. Similarly, certified firms are 16 percent more likely that non-certified firms to invest in new technology, holding other variables at their mean values.

The empirical findings have several policy implications. First, there is a need to provide a supportive environment to new export-oriented enterprises as these enterprises are likely to play a leading role in adoption of new technology. A key initiative could be the provision of tax credit on research and development expenditure. This would provide an incentive to such enterprises to upgrade and maintain their technological competencies. Second, there is a need to create a level playing field between domestic and foreign investors. Various incentives that are routinely provided to foreign investors should also be extended to domestic enterprises especially when the latter are more likely to invest in new technology in line with market requirements. Third, technical certifications not only help exporters to gain market share but are also instrumental in encouraging firms to adopt new technology. Unfortunately, however, obtaining certifications of conformity to various product and process standards has been highlighted as a major constraint in Pakistan. There is, therefore, a need to facilitate certifications through fiscal incentives as well as through helping to upgrade and establish the necessary physical infrastructure for technical testing.

4. CONCLUDING REMARKS

This paper has analysed the factors influencing the probability of technology adoption by export-oriented firms using survey data of export-oriented enterprises. Employing the rank model of technology adoption, firm-specific characteristics such as age, volume of sales, firm size, type of ownership, certification to standards, and geographical location have been explored as possible factors influencing firms' decision to adopt new technology. The results show that younger and bigger firms have a higher probability of technology adoption. Similarly, firms with higher sales are more likely to adopt new technology. Firms that have obtained certifications of conformity with international product and process standards demonstrate a higher likelihood of technology adoption. Domestically-owned firms are found to have a higher probability of technology adoption as compared with foreign-owned firms due perhaps to the use of lower-end technology by the domestic firms in relation to the foreign-owned firms.

The empirical findings have important policy implications. First, new enterprises have demonstrated a higher likelihood of technology adoption and thus need to be nurtured through proper fiscal incentives for technology adoption including tax credits for research and development activities. Second, the domestically-owned enterprises should be offered the same incentives package as are made available to foreign-owned firms to enable them to continue investing in better product and process technologies. Finally, facilitation of certification to technical standards can be instrumental in promoting adoption of new technology by the export-oriented enterprises.

APPENDIX

Dependent Variable: Yi Method: ML - Binary Probit				
Variable	Coefficient	Std. Error	z-Statistic	Prob.
C	–1.77	1.07	–1.66	0.10
LAGE	–0.42	0.21	–1.99	0.05
DSIZE	0.97	0.37	2.59	0.01
LOCATION	0.28	0.33	0.85	0.40
LSALES	0.28	0.11	2.60	0.01
CERT	0.58	0.37	1.58	0.11
OWN	0.68	0.47	1.44	0.15
LR statistic (6 df)	35.24	McFadden R-squared	0.31	
Probability (LR stat)	0.00			

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Comments

The paper titled 'An Analysis of Technology Adoption by Export-oriented Manufacturers in Pakistan.' It is an excellent paper that analyses the issue of technology adoption by 4 major export industries of Pakistan including textile, leather product, agro-food and fisheries. The authors have identified 6 characteristics; age, size, location, volume of sales, status of certification and ownership that may affect technology adoption. The conclusion is that young and large firms adopt new technology more often than old and small ones. Location has insignificant effect while certification and ownership by locals have positive effect.

Following points may be useful for further improvement of this paper.

- Technology adoption and ownership have been taken as binary variables; yes or no and domestic or foreign respectively. They can better be defined as percentage of total annual expenditures spent on new technology adoption and percentage share of foreign ownership in a given firm respectively.
- Both size and volume of sales represent the size of firm, therefore one of them may be omitted.
- Spatial clustering generates external economies of scale as best practices in one firm foster demonstration effect for others. Keeping this fact in view, taking Karachi as the only clustering location seems somewhat inappropriate. It is quite possible in other cities as well.
- The authors may consider ranking of 4 sectors considered in the research with respect to technology adoption. That is they want to answer the question; which sector adopted new technology at first and which one at the last.
- Some financial variables like debt equity ratio, price earning ratio and return on equity should have been included in the list of explanatory variables.

Policy implications of this research are very clear and worth serious consideration of policy-makers.

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