WORKING PAPERS

EAST-WEST CENTER WORKING PAPERS

EAST-WEST CENTER

Publication Sales Office
East-West Center
1601 East-West Road
Honolulu, Hawaii 96848-1601

Telephone: 808-944-7145
Facsimile: 808-944-7376
Email: ewcbooks@EastWestCenter.org
Website: www.EastWestCenter.org

EAST-WEST CENTER WORKING PAPERS

EAST-WEST CENTER

Economics Series

No. 21, May 2001

Does Investing in Technology Affect Exports?

Evidence from Indian Firms

Rana Hasan and Mayank Raturi

Rana Hasan is a Fellow at the East-West Center. This paper is part of his research on the effects of market-oriented economic reforms on productivity growth.

Mayank Raturi is a Researcher at Swissre. Dr. Raturi attained his Ph.D. from the University of Maryland and is a former researcher for the World Bank.

East-West Center Working Papers: Economics Series is an unreviewed and unedited prepublication series reporting on research in progress. The views expressed are those of the author and not necessarily those of the Center. Please direct orders and requests to the East-West Center's Publication Sales Office. The price for Working Papers is $3.00 each plus postage. For surface mail, add $3.00 for the first title plus $0.75 for each additional title or copy sent in the same shipment. For airmail within the U.S. and its territories, add $4.00 for the first title plus $0.75 for each additional title or copy in the same shipment. For airmail elsewhere, add $7.00 for the first title plus $4.00 for each additional title or copy in the same shipment.

Does Investing in Technology Affect Exports?
Evidence from Indian Firms

Rana Hasan
East-West Center
1601 East-West Road
Honolulu, HI 96848
e-mail: hasanr@ewc.hawaii.edu

and

Mayank Raturi
Swissre
55 East 52nd Street
New York, NY 10055
e-mail: Mayank_Raturi@swissre.com

May 2001

ABSTRACT

We use firm-level data from Indian manufacturing industries to explore the determinants of exports, focusing especially on the role of technology. Our empirical analysis is based on a two-part estimation strategy whereby we first explore which factors influence a firm's participation in export markets and then explore which factors influence the volume of exports of exporting firms. Our results reveal that technology related activities, including investments in R&D and technology transfers from foreign firms, can play a useful role in enabling firms to enter export markets. This is especially so in the scientific group of industries where the scope for technological advances tend to be large and where design changes in both products and processes can be frequent.

However, our results also suggest that technology alone is unlikely to be the basis on which India's manufacturing sector can expand its exports significantly. In particular, our results indicate that the most important determinants of export volumes turn out to be firm size and labor intensity. From a policy perspective these results have a special relevance for the ongoing debate on India's reform efforts. Although the liberalization process which began in earnest in 1991 has alleviated many of the restrictions that industrial policy imposed on firm size, India continues to reserve certain labor intensive products exclusively for small-scale production. If large firms have an advantage in exporting, and the estimates here certainly lend strong support to this view, then the policy of reservation is likely to remain a drag on Indian exports of products in which labor abundant India should have comparative advantage.

ACKNOWLEDGEMENTS

We are extremely grateful to the Institute for Studies in Industrial Development of New Delhi, India for allowing us to use the firm-level data utilized in this study. We have benefited from discussions with Tianshu Chu, Bill Evans, Jesus Felipe, Haider Khan and Chelapati Rao. We thank Eugene Alexander for excellent secretarial assistance. All errors are our responsibility.

Does Investing in Technology Affect Exports? Evidence from Indian Firms

1. Introduction

A number of studies have found a positive relationship between the exporting status of firms in developing countries and their productivity (for example, Clerides, Lach, and Tybout, 1998; Aw and Batra, 1998; Aw and Hwang, 1995; Tybout and Westbrook, 1995; Chen and Tang, 1987).[1] Given the widely held belief that export orientation among firms facilitates and/or encourages the adoption of international best practices and new technologies, the finding is partly attributed to differences in technology among exporting and non-exporting firms. These differences may arise as a result of the possibility that exporting firms receive free or more effective transfer of technical knowledge by foreign buyers. Alternatively, exporting firms are likely to face a more competitive environment than firms, which cater to a protected domestic market. This may require exporting firms to invest more in upgrading their technical knowledge and/or using inputs embodying superior technologies than otherwise (World Bank, 1998; Evenson and Westphal, 1995; World Bank, 1993).[2]

In this paper, we examine the latter channel linking exports and technology. In particular, we use data from Indian manufacturing firms to examine the impact of various firm-level indicators of technology, including technical knowledge acquired via R&D and technology transfer agreements with foreign firms (imported technology), on firms' exporting behavior. While Indian manufacturing firms are not known for export dynamism, a number of them do invest a fair amount in technology by developing country standards. Moreover, while they have largely been motivated in doing so by considerations of the protected, domestic market their investments in technology may be expected to impact firms' exports positively if these improve product quality and/or provide for a more streamlined production process.

Similar issues have been examined by Kumar and Siddharthan (1994). However, unlike Kumar and Siddharthan who use a tobit model to examine the relationship between firms' exports (their dependent variable) and various firm-specific factors, we conduct our analysis using a two-part estimation framework which distinguishes between a firm's decision to export and the volume of its exports conditional on its having decided to export. Correspondingly, estimation consists of two parts or stages. In the first stage we consider the issue of what influences the decision of a firm to export using a probit model. Next, using the sample of exporting firms, we examine what explains the volume of exports using linear regressions.

The reason we prefer to use the two-part model over the tobit model for analyzing the exporting behavior of firms is as follows. As emphasized by Duan et al. (1984) and Lin and Schmidt (1984) among others the use of the tobit model is appropriate when the dependent variable is truly censored, i.e., when there exists a range of values for which the dependent variable is *reported* as a particular value. In an application like ours where firms' export volume is the dependent variable, zero values for exports - which occur for about a third of our sample - are precisely that and do not reflect censoring of the data.

---

[1] Productivity is captured in different ways in these studies. Clerides, Lach, and Tybout use panel data from Colombia, Mexico, and Morocco and measure productivity in terms of average variables costs and labor productivity; Aw and Batra and Chen and Tang use cross-section data on Taiwanese firms and estimate production frontiers for export and domestically oriented firms; Aw and Hwang compare the intercept and slope coefficients across separate production functions for Taiwanese firms; and Tybout and Westbrook use panel data on Mexican firms to estimate production and cost functions using a random effects model and use the predicted firm-specific error term to measure productivity.

[2] Clerides, Lach, and Tybout find little support for the view that firms acquire efficiency-enhancing technical knowledge by exporting. Instead, firms which enter export markets tend to be the more efficient ones.

As is shown later, using the tobit model to account for the discontinuity of a dependent variable not caused by censoring involves a misspecification.

In addition, the tobit model forces one set of parameters to determine both the firm's decision to export as well as the volume of its exports. If a variable influences one decision and not the other (or worse, influences the two decisions in qualitatively different ways) the tobit model will be unable to pick up on this distinction. In contrast, because the two-part model treats both decisions separately it does not suffer from this drawback. Indeed, as the recent work on entry into export markets highlights the response of aggregate exports to a policy stimulus depends not only on how incumbent exporting firms adjust to the stimulus, but also on whether the policy stimulus affects the set of producers who export (Roberts and Tybout 1997). Thus measures which are aimed at increasing export levels do not need to coincide with measures aimed at promoting entry of non-exporting firms into export markets and the distinction can be important for countries contemplating export promotion policies.

Our results indicate that firms with larger stocks of R&D and imported technology are in a better position to enter export markets. Moreover, entry is also facilitated by a skilled workforce, foreign equity, a labor intensive production process, and firm size. However, higher stocks of technical knowledge are not associated with higher export volumes among exporting firms, suggesting that while such investments in technology can facilitate Indian exports they are not a critical ingredient. Instead, export volumes tend to increase with firm size, labor intensity, the availability of imported production inputs, and in some instances, foreign equity. Among other things, the latter set of results serves to highlight the possibility that some features of India's current regulatory regime, such as the continued reservation of certain products for small scale production and stringent job security laws which encourage large firms to adopt capital intensive production processes, may be unduly constraining Indian exports.

The remainder of this paper is organized as follows. Section 2 describes the links between technology and exports and presents the framework we use to explore these linkages, including details on the estimation framework we adopt. Section 3 discusses our data set and the construction of variables used in estimation. Section 4 describes our empirical findings and Section 5 concludes with a summary of our main findings and some remarks on the policy implications of our results.

2. Conceptual Framework and Estimation Issues

Exports and Technology

What factors cause one firm to export but not another? Although trade theory tends to be muted on this question, some recent research has focused its attention on various aspects of this issue. Case study evidence and surveys of firms indicate that entry into export markets is complicated by a number of factors including inadequate quality of products and/or high production costs – especially in more protected markets where the access of firms to imported inputs is restricted by quotas or made expensive by tariff barriers – limited access to trade related finance and services, and uncertainty about trade and exchange rate regimes. In addition, there may be a host of informational barriers between domestic producers and potential foreign buyers. For example, foreign buyers may be ignorant about the capabilities of domestic suppliers; similarly, domestic suppliers may have limited information about foreign markets and tastes (Vakil, 1996, Aitken et al, 1997; etc.). [3]

[3] Indeed, motivated by such episodes as the boom in garment exports by Bangladeshi firms following the successful entry of one Korean garment exporter in Bangladesh, Aitken et al (1997) use panel data from Mexican firms to examine how important informational spillovers are to exports. Controlling for a number of factors, which have plagued earlier studies, Aitken et al find that locating near multi-national enterprises, but not other exporters, increases the probability that a domestic firm will export. They conclude that multi-nationals are an important source of information about foreign markets and technology and distribution services.

Given the importance of product quality and cost competitiveness in export markets, it would not be out of place to expect that technologically more dynamic firms may be particularly well placed to compete abroad: investments in technology are likely to lead to better quality and/or a more streamlined production process which results in lower costs of production and thereby improve export competitiveness. This should be true even in the context of a highly protected and regulated economy such as India, where an import substitution strategy combined with a rigid policy of industrial licensing is believed to have led to relatively inelastic demand in a domestic market which was large enough to absorb most production and where exports were treated as a "residual market" (Vakil, 1996).[4] In such an environment, firms' investments in technology may well be aimed at the domestic market – as the case study evidence of Bell and Scott-Kemis (1985), Desai (1985), and Lall (1987) indicates – but the investments in technology may help them compete in foreign markets if the need arises.

Our indicators of technology include both disembodied and embodied measures. For the former we construct stocks of technical knowledge generated by firms' investments in R&D and their purchases of technology from foreign firms via technology transfer agreements (henceforth referred to as technology imports/imported technology). However, while R&D and technology imports are "formal" modes of adding to technical knowledge it is well known that there are many "informal" means by which a firm's stock of technical knowledge may be augmented, as when an innovation is generated at the shop floor level or better production practices lead to a more efficient production process, for example.

Although informal efforts at technology generation are difficult to quantify we include a measure of the skill of a firm's workforce and an indicator for foreign equity in the firm to capture these. A relatively skilled workforce is likely to be more productive. Similarly, a stake in profits may encourage foreign partners to introduce superior managerial practices and also ensure that any technologies transferred are managed effectively.[5] It is important to note, though, that domestic firms with foreign equity are also likely to find it easier to export on account of their access to the international marketing networks of their foreign partners. This would hold even in an inward looking country like India where much foreign direct investment (FDI) is of the tariff and quota jumping variety and, therefore, primarily oriented towards accessing the domestic market.[6]

As for embodied technologies, it is well recognized that imported inputs are especially likely to embody productivity enhancing technologies. Thus we use information on firms' imports of production inputs to capture embodied technology.

In addition to these various measures of technology, we also include in our analysis of exporting behavior the effects of the capital intensity of the production process and a measure of firm size. Given the relatively abundant supply of labor in India, it would be reasonable to expect Indian firms to be

[4] Indeed, as we shall see in Section 3, the data on the sample firms are consistent with the view that exports were a residual market: While a majority of sample firms do export (almost 66%), the ratio of exports to net sales tends to be very low. For example, among exporting firms even the 75th percentile value of this ratio is less than 10 percent.

[5] In principle, foreign technology that is purchased through an arms length contract may be as effective as that linked with equity flows. However, recent research which emphasizes the distinction between knowledge that is "tacit" as opposed to "formal or codified" suggests that technology flows linked with equity may be more productive. This is because although the formal or codified technology is both easily transferable (for example, through manuals, codified operating procedures, etc.) and monitorable by the purchaser of the technology, tacit knowledge may not be. In other words, the transfer of tacit knowledge typically requires extensive face-to-face contact and a willingness by the originator of the technology to part with it (see Arora, 1996 for a discussion). Both conditions are much more likely to be satisfied in equity-linked technology transfer agreements.

[6] This is borne out by the sample data. The 75th percentile value of the ratio of exports to net sales for firms with foreign equity is only around 8 percent.

competitive in the production and export of relatively labor intensive products and/or production processes. Similarly, to the extent that production is characterized by economies of scale and/or participation in export markets entail fixed/sunk costs we would expect larger firms to find it easier to enter and compete in export markets. As Roberts and Tybout (1997) point out maintaining a presence in export markets involves incurring fixed costs such as dealing with customs, paying minimum freight and insurance charges, etc. In addition, there are also start-up costs associated with entry into markets. These costs are incurred on account of the need to learn about foreign regulations and market requirements, establish foreign distribution channels, etc. Larger size can enable a firm to spread its expenditures on fixed and start-up costs over a larger volume of production. If these fixed and start up costs are important, as Roberts and Tybout find is the case, then larger size should facilitate entry into export markets.[7]

Estimation Issues

One of the most striking features of the data is the large number of observations with zero values for firms' exports. Strictly speaking then, this variable is not continuous and if it is to be used as the dependent variable in a regression model, an appropriate estimation technique should be used. A commonly used strategy for estimating a regression equation where the dependent variable takes on a mixture of discrete (zero) and continuous values is to employ the censored regression or tobit model. However, this is not quite appropriate in the current context. In the tobit model, values of the dependent variable lying in a particular range are all reported as a single value. That is, the tobit model is used in the case where the true values of a particular variable y_i^*, distributed as $N(X_i \cdot \beta, \sigma^2)$, are reported in the form: $y_i = 0$ if $y_i^* \leq 0$; and $y_i = y_i^*$ if $y_i^* > 0$.

However, in a regression equation with exports as the dependent variables, zero values for exports are precisely that. They do not represent negative exports. Using the tobit model for analysis, therefore, involves the misspecification of the probability that y_i^* is less than zero. More seriously, the tobit model forces one set of parameters to determine both the probability of a limit observation (i.e., a zero value) as well as the density of the non-limit observations (i.e., those with positive values). Thus, a variable, which increases the probability of a non-zero value will simultaneously lead to an increase in the mean of the positive values. For example, suppose the coefficient B_1 on a regressor X_1 derived from a tobit model is positive. Then a higher value of X_1 must be interpreted as not only raising $Prob(y_i>0)$, but raising $E(y_i|y_i>0)$ as well. In our context, if technical knowledge influences entry into export markets but not export levels of exporters, then the tobit will miss this feature of the technology-exports relationship.

An alternative estimation model, which does not suffer from the above mentioned problems is the two-part model. In this model, two processes are assumed to generate the data. In terms of our exports problem, the first process involves the decision on whether to export or not. This is followed by the decision on how much to export *conditional* on having decided to export. In order to derive the likelihood function for this model, let P_i represent the probability that firm i's exports are zero, i.e. $P_i = Prob(y_i=0)$. Additionally, let $g(y_i)$ represent the probability density function of y_i conditional on y_i being greater than zero. We can therefore write the probability density function of y_i as: P_i if $y_i = 0$; and $(1-P_i) \cdot g(y_i)$ if $y_i > 0$. Thus $E(y) = P_i + (1-P_i) \cdot \int y \cdot g(y)\, dy$.

To estimate the model, suppose there is an equation, which determines whether or not a firm exports. That is, let E_i^* denote the profitability of exporting, such that:

$$E_i^* = \gamma \cdot X_i + \varepsilon_{1i} \qquad (2.1)$$

7 Indeed, Berry's (1992) survey on the relationship between firm size and trade-related performance indicates, manufactured goods exports from developing countries tend to be produced by relatively large firms.

where X represents a vector of variables which influence the profitability of exporting and $\varepsilon_{1i} \sim N(0,1)$. While E_i^* is unobserved, we do observe whether the firm exports or not, i.e. whether $E_i=1$ (when $E_i^*>0$) or $E_i=0$ (when $E_i^*\leq 0$). Thus, the probability that $E_i^*>0$ may be expressed as $\text{Prob}(E_i^*>0) = \text{Prob}(E_i^*>-\gamma\cdot X_i) = \Phi(\gamma\cdot X_i)$.

Now, we can suppose that for firms, which do export, the following equation determines how much they export:

(2.2)
$$Y_i = \beta \cdot X_i + \varepsilon_{2i}$$

where $E(_{2i} \mid E_i^*>0)=0$ as in Duan et al (1984). Letting $f(\varepsilon_{2i})$ be the probability distribution function of ε_{2i}, not necessarily normal, the likelihood function for firm i then has the following form:

(2.3)
$$L_i = [1- \Phi(\gamma\cdot X_i)]^{(1-E_i)} \cdot [\Phi(\gamma\cdot X_i) \cdot f(\varepsilon_{2i})]^{E_i}$$

The log-likelihood over all observations is:

(2.4)
$$\sum_{i=1 \text{ to } N} ([1 - E_i] \cdot \ln(1- \Phi(\gamma\cdot X_i) + E_i \cdot [\ln(\Phi(\gamma\cdot X_i)) + \ln(f(\varepsilon_{2i}))])$$

and can be factored into two parts. The first is composed of the first two terms of equation (2.4) and involves the parameters in equation (2.1) while the second is composed of the last term in equation (2.4) and involves parameters from equation (2.2). Thus, the estimation problem can be broken into two parts. In the first, a probit model is estimated to determine the probability that a firm will export. In the second, and using only the sample of firms, which export, OLS is used to determine how the various explanatory variables impact the volume of exports.[8]

A potential complication in estimation stems from the possibility of endogeneity of our regressors, especially those relating to technical knowledge. For example, suppose that formal investments in technical knowledge are correlated with an unobservable such as managerial ability (investing in technical knowledge entails considerable risk and may be attempted by only the most able). If the ability to compete in demanding export markets is also correlated with managerial ability, then the exclusion of a measure of managerial ability in the regression equation will lead to an overestimate of the impact of technical knowledge on exports. One way to deal with this problem is by using the method of instrumental variables (IV).[9] In practice, however, it is very difficult to find suitable instruments, i.e. variables which are correlated with the independent variable in question but not the dependent variable. Nevertheless we make an attempt to find such variables and correct any potential endogeneity in our measures of technical knowledge using 2SLS. However, to the extent that our IV estimates are estimated

[8] It has been claimed that for $E(,_{2i} \mid E_i^*>0)=0$ to be consistent with the set up in equations (2.1) and (2.2), either $\text{Cov}(,_{1i}, ,_{2i})$ must be assumed to be zero, or some "fairly unusual assumptions" must be made regarding the distributions on the error terms $,_{1i}$ and $,_{2i}$ (Hay and Olsen, 1984). However, Duan et al (1984) show that this is not the case. As long as the primary goal is to predict the actual outcome, in our case the actual exports, rather than potential outcome or exports, a non-zero correlation coefficient D (where $\text{Cov}(,_{1i}, ,_{2i})=D$) does not enter into the likelihood function and is, therefore, "irrelevant for the purpose of estimating the two-part model" (page 286). Nevertheless, we also used Heckman's two-step procedure to obtain estimates of equation (2.2), which explicitly account for a non-zero correlation coefficient between the two-error terms $,_{1i}$ and $,_{2i}$. Identification was achieved using a dummy variable for exporting history as instrument in the first stage probit model. The final results were very similar to those obtained by the two-part model and are not reported.

[9] Note that using an IV-type procedure in the first stage probit model is currently infeasible given the discontinuous nature of the technology stock variables - the potentially endogenous right hand side variables. If these variables were continuous the procedure of Rivers and Vuong (1988) could have been used (as in Aitken et al, 1997). However, an IV procedure may be used for equation (2.2).

with reasonable precision they not very different from our OLS estimates and we therefore focus on only the latter in the text.[10]

3. The Data

Variable Construction

The data we use for estimation comes from the annual reports of 685 public listed firms, defined as private corporations with more than 50 shareholders, covering three years (1988-89 to 1990-91).[11] The firms belong to 11 industries at the two-digit level and span the broad range of the manufacturing sector. The firms may also be classified into scientific and non-scientific industry groups. The scientific group of industries contain 369 firms belonging to the chemicals (including pharmaceuticals), electrical, non-electrical, rubber products, and transportation equipment producing industries. The remaining 316 firms belong to the food, cotton textiles, other textiles, paper and allied products, cement, and metallurgical industries and make up the non-scientific group.[12] As will be noted later, firms in the scientific group accumulate far more technical knowledge on average than those belonging to the non-scientific group.

We measure (formal) technical knowledge by utilizing information on firms' expenditures on R&D and imports of technical knowledge from foreign firms. Because technical knowledge can be long-lived and is best conceptualized as a stock variable we are clearly constrained by having only three years of data; nevertheless, constructing stocks of technical knowledge using three years data is presumably better than assuming that investments in technical knowledge become obsolete in one year - an assumption implicit in related empirical work (for example, Aw and Batra, Kumar and Siddharthan). Thus we sum up expenditures on R&D and imports of disembodied technology over the three years allowing for some depreciation of knowledge over time:

(3.1) $$KT_{i\,91} = T_{i\,91} + T_{i\,90} \cdot [1-\delta] + T_{i\,89} \cdot [1-\delta]^2, \quad T=RD, MT$$

where RD and MT represent real annual expenditures on R&D and import of disembodied technology, respectively, and δ represents a rate of depreciation assumed to be equal to 15 percent.[13,14,15] One result of our usage of a stock measure of technical knowledge is that it forces us to concentrate on a cross-

---

10 The IV estimates are reported in an appendix.

11 The firms report this information to the Reserve Bank of India, India's central bank.

12 This classification essentially divides the low-, medium-, and high-technology breakdown of UNCTAD used by Kumar and Siddharthan into a scientific (high- and medium- technology) and non-scientific (low-technology) group of industries. It also corresponds with the classification of firms used by Griliches and Mairesse (1984) and Basant and Fikkert (1996).

13 A cross-checking of the R&D numbers from the firms' annual reports with those contained in the Ministry of Science and Technology publications, Research and Development in Industry 1990-91 and the Compendium on In-House R&D Centers, revealed that a number of firms failed to itemize their R&D expenditures in their annual reports. The R&D expenditures reported to the Ministry of Science and Technology, considered a very reliable source for such information, were used to fill in the missing data on R&D. The cross-checking also revealed that in some cases, firms with foreign equity did not report it in their annual reports. A correction for this variable was also made.

14 The deflator for expenditures on acquiring technical knowledge is constructed as the average of the wage and capital goods deflators. The former is derived from the Annual Survey of Industries while the latter is the wholesale price index of machinery from Chandhok (1991).

15 Parameter estimates are typically found to be fairly robust to a relatively wide range of depreciation rates (see Griliches and Mairesse, 1984, for example).

sectional analysis. The main drawback of this is that it constrains us from controlling for firm-effects, which may be correlated with the firms' decision regarding exports and input choices, through the usage of an appropriate panel data estimator. However, since there are only three years available in the first place, this is not likely to be too much of a loss: as is well known, panel data methods which control for firm-effects can be very "costly" in terms of reducing the overall variation within any given data set. With only three years of data, the gains are very likely to be outweighed by the costs.[16]

For the other variables construction is quite straightforward. The skill intensity of operations is captured by the fraction of salaries, wages, and bonuses composed of payments to high-income personnel in the first year of the data (i.e., those earning Rs. 72,000 per annum). The importance of embodied technology is measured by the ratio of imports of equipment and raw materials to net sales. Firm size is measured by the value of total gross fixed assets. The capital-labor ratio is computed as the ratio of total gross fixed assets to total payments for salaries, wages and bonuses. Finally, information on foreign equity is captured variously through dummy indicators and the fraction of foreign equity in total equity.

Basic Characteristics of the Sample Firms

Table 1 presents mean values of various variables by two-digit industry and by scientific and non-scientific industry groupings. On average firms in the scientific group export more often, have larger exports, spend more on acquiring technology, and are more often characterized by the presence of foreign equity. They also tend to be larger as is indicated by the numbers on sales and capital stock.

Some interesting relationships between the variables may be gleaned by examining the data on the basis of market orientation, i.e., whether a firm exports or not, and on the basis of stocks of technical knowledge, i.e. whether a firm conducts R&D or imports technology or not. Tables 2a and 2b present these by scientific and non-scientific groups. When the data are viewed in terms of market orientation, as in Table 2a, it is clear that on average exporting firms in both groups make a larger commitment to acquiring technical knowledge, have higher skill intensity of operations, utilize imported equipment more intensively, are characterized by the presence of FDI more often, and are less capital intensive. Exporting firms in both groups also tend to be larger in terms of both sales and capital stock.

Interestingly, when the same data are viewed in terms of investments in technical knowledge, the overall patterns are very similar. That is, on average firms with non-zero stocks of technical knowledge in both groups tend to have higher skill intensity of operations, utilize imported equipment more intensively, be characterized by the presence of FDI more often, and be larger in terms of both sales and capital stock. They are also more likely to export as well as export more (though not necessarily as a proportion of sales).[17]

Thus there appear to be a number of broad similarities between exporting firms and firms which invest in technical knowledge. One difference is in their capital intensity of operations, however. While exporting firms tend to be less capital intensive on average in both scientific and non-scientific groups, this is not necessarily the case for firms that invest in technical knowledge.

The comparison of simple averages across groups does suggest that having a larger stock of technical knowledge may help in export markets. However, there is a lot of variation within groups and

---

[16] Moreover, the inclusion of other firm-specific variables likely to be correlated with firm-effects - such as size and presence of foreign equity - as regressors may alleviate problems associated with the omission of firm-effects.

[17] These patterns generally repeat themselves at the level of individual industries.

industries and since there appear to be many other similarities on average between firms which export and invest in technology, it is important to control for these other factors before we can arrive at a more definite conclusion. The results of the regressions reported next do just that.

4. Empirical Results

Participation in Export Markets

The first set of results pertain to the firm's decision to participate in export markets as captured by the standard probit model. Because the probit model cannot be estimated for all of the two-digit industries separately we pool firms into the more aggregated scientific and non-scientific groups.[18] Pooling firms this way also has the benefit of allowing coefficients to be estimated more precisely and making them less susceptible to small sample biases inherent in the smaller two-digit industry groups. However, because exports are likely to be influenced by industry level characteristics, we include industry specific dummies in every model we estimate. Among other things, these dummies will pick up industry level differences in the attractiveness of domestic markets relative to foreign markets for firms, whether caused by differences in the relative price of output across domestic and foreign markets, demand conditions operation at home versus abroad, etc.

In addition to assigning firms into scientific and non-scientific groups, we also split them into sub-groups depending on whether they are engaged in acquiring technical knowledge through either R&D or imports. As is clear from Table 2b above a large number of firms are able to export without making any formal investments in technical knowledge. If such firms' produce standardized good – i.e. goods, which are characterized by slow or infrequent changes in design – they may in effect be catering to a different segment of the export market in comparison with firms, which do make formal investments in technical knowledge. Separate estimation of the export decision for firms, which formally invest in technical knowledge and those that do not will then capture more accurately its determinants. In what follows we refer to firms, which invest in technical knowledge as "high-tech" and those that do not as "low-tech" as in Aw and Batra (1998).

Tables 3a and 3b detail the results of various probit models for the scientific and non-scientific groups, respectively. There are three sets of estimates based on how foreign equity is introduced in the equations. In the first and second, dummy variables capture the presence of either any foreign equity or foreign equity greater than 20 percent of total equity, respectively, while in the third the share of foreign equity in total equity is used.[19]

Taken together the various estimates reveal that R&D and imports of technology increase the probability of exporting, especially for firms in the scientific industries and high-tech sub-groups. The probability of exporting also increases with the extent of foreign equity, a skilled workforce, a labor intensive production process, and larger size.

More specifically, we find that R&D stocks increase the likelihood of exporting for scientific firms both generally as well as for the high-tech subset. Stocks of imported technology are also associated with a higher probability of exporting but only among the high-tech sub-group. Technology

[18] An explanatory variable, say KMT, can be included in estimation of the probit model if the minimum value of KMT for which a firm exports (does not export) is less than the maximum KMT for which the firm does not export (exports). Violation of either condition leads to a breakdown of the probit estimation procedure (Greene 1995). In textiles (other than cotton) and rubber products there is no firm which imports technology and doesn't export. In particular, the minimum KMT for which a firm exports is zero which is <u>not</u> less than the maximum value of KMT for which a firm does not export, also zero.

[19] Most independent variables are introduced in logs. The exceptions are the FDI dummy variables and the ratios which range from 0 to 1 (i.e., skill intensity, import intensity, and share of foreign equity).

stocks play a more limited role in the non-scientific group: the effects of R&D are uniformly negligible and when the stocks of imported technology affect the probability of exporting significantly, they do so only for the high-tech sub-group. The fact that neither of the two stocks of technical knowledge is statistically significant in explaining the probability of exports for the non-scientific firms taken as a whole indicates, in accordance with intuition, that there is considerable scope for exporting standardized (or low-tech) products in the non-scientific industries. This tends not to be the case in the scientific industries where R&D stocks do confer an advantage in entering export markets for the group as a whole.

With the exception of low-tech firms in the non-scientific industries where very few firms have any foreign equity in the first place (as may be confirmed from Table 2b), firms with a higher fraction of foreign equity in total equity are more likely to export as may be seen from the positive and typically statistically significant estimates on FDI in Tables 3a and 3b. The skill intensity of the workforce is robustly associated with a higher probability of exporting with virtually every estimate in Tables 3a and 3b showing up significant at the 10 percent level or better. The probability of exports also tends to increase with a more labor intensive production process as the negative and usually significant coefficients on the K/L variable indicate in Tables 3a and 3b. Finally, larger size is typically associated with a higher probability of exporting.

Because of the nonlinear nature of the probit model, the estimated coefficients do not directly inform us about the magnitude of the impact of the regressors on the probability of exporting. These, however, may be derived by computing the marginal effects. Table 4 details the marginal effects of the probit models based on the share of foreign equity in total equity as the measure of FDI. As the numbers reveal, a one percent increase in KRD and KMT raises the probability of exporting of high-tech, scientific firms by 1.1 and 0.8 percentage points, respectively (second and fifth data columns). The corresponding numbers for the high-tech, non-scientific firms are 1 and 1.5 percentage points (although the effect of KRD is not statistically significant).

In comparison to the effects of size and labor intensity, however, these are not large impacts. A one percent increase in a firm's total capital stock (our measure of size) increases the probability of exporting by 11 percentage points for the scientific group as a whole, though it should be recognized that stocks of knowledge capital are much smaller to begin with than physical capital and thus there is greater scope to raise the former. Interestingly, the numbers here suggest that a more labor intensive production process can be particularly effective in raising the probability of exporting: a one percent decline in capital intensity can be associated with a rise in the probability of exporting by as much as 13 percentage points (first and second data columns). A greater foreign share in total equity and a more skilled workforce also have fairly large impacts on exporting.[20] For example, a one percentage point increase in foreign equity is associated with a 0.32 percentage point increase in the probability of exporting for the scientific group as a whole while a one percentage point increase in the skill intensity variable is associated with a 0.94 percentage point increase in the probability of exporting.

Export Volumes of Exporting Firms

Consider next the factors, which influence the export volumes of exporting firms. Tables 5a and 5b describe the results of the linear regression model for exporters in the scientific and non-scientific industries, respectively. As in the case of the probit models, there are three sets of estimates based on the manner in which foreign equity is introduced in the regression equation.

[20] Because foreign equity and skill intensity are introduced as simple ratios in the estimating equations their coefficients need to be interpreted differently in comparison with the other variables which expressed in logs.

The results indicate that a labor intensive production process, greater usage of imported inputs, and, especially, larger size typically influence export volumes positively. However, higher stocks of technical knowledge are not associated with higher export volumes among exporting firms. In fact, some of the estimates in Table 5b indicate that stocks of imported technology are associated with *lower* exports in the non-scientific industries. Similarly, the effects of FDI on export volumes are mixed in comparison with the case of export participation.

To some extent, the negative impact of imported technology on export volumes in Table 5b is the result of pooling high-tech and low-tech firms together: the negative sign stocks loses its statistical significance when only high-tech firms are considered suggesting, in accordance with intuition, that the market for standardized products is more promising for Indian manufacturing firms seeking to export.

However, this is unlikely to be the complete story since at least within the high-tech subgroups of both scientific and non-scientific industries one would expect higher technology stocks to lead to higher export levels. The fact that they do not, despite raising the probability of exporting (in many cases in Tables 3a and 3b), seems to suggest two things. First, and perhaps most importantly, it suggests that at the level of technological sophistication that even high-tech Indian firms operate, technology is not a very important factor on which the export competitiveness of Indian firms' products depends. As described earlier, Indian firms' investments in technical knowledge have been motivated by the circumstances relating to the protected, domestic market. Some of the accumulated technical knowledge is useful for firms' entry into export markets but beyond this the competitiveness of firms' products appears to be determined by other factors.

Second, while the link between exports and technology stocks emphasized in this paper relies on quality and/or cost considerations, technology stocks may also affect exports through another channel. As discussed above, informational barriers between domestic producers and potential foreign buyers can be an important impediment to entry into export markets. Firms which invest in technical knowledge are at an advantage in this regard as they are likely to already possess links with foreign firms. Consider the import of technology. Foreign technology does not simply come off the shelf. As case study evidence from India reveals, firms seeking to purchase foreign technology must search among many potential suppliers of technology. The process of this search exposes the Indian firm to the foreign market for the product it produces and can thereby lower the information-related barriers to entry into export markets. This would then be consistent with the pattern of results obtained whereby imported technology stocks are associated with a higher probability of exporting but fail to impact export levels of exporters positively. To some extent this same process would work for R&D investments. This is because the case study evidence also suggests that many Indian firms, which carry out their own R&D do so after having failed to import the technology required (Bell and D. Scott-Kemmis, 1985). The failure may be due to any number of reasons; the point here is simply that even these firms would have carried out a search of foreign firms and may therefore be possessing a better knowledge of conditions in foreign markets.

An informational role is also certainly possible, and even very likely for foreign equity. This is especially suggested by the estimates for the non-scientific firms where despite a fairly typical positive and significant impact on exporting probability, foreign equity is associated with lower exports, significantly so in one case. Thus while FDI in India's non-scientific firms may have been driven by the desire to serve the domestic market it may have enabled firms to enter export markets more easily by lowering the barriers to entry. But clearly FDI can play a more important role than just alleviating entry barriers into export markets as the estimates for the scientific firms reveal. In terms of the estimates of the second last column of Table 5a, for example, a 10 percentage point increase in the share of foreign equity is associated with a 0.157 percent increase in exports as the second last column shows.[21]

[21] An informational role could also be made out for the skill intensity of a firm's workforce based only on the fact that it

As mentioned earlier, the variables with a more broad-based positive influence on export volumes are the labor and import intensity of production and size. A decrease in capital intensity raises exports in all cases, although the effect is mainly significant for high-tech firms. For example, as the last set of estimates in Tables 5a and 5b indicate, a 1 percent decline in capital intensity can lead to an increase in exports of 0.59 percent in the scientific group and 0.76 percent in the non-scientific group among high-tech firms. In contrast to its lack of an effect on the probability of exporting, an increase in import intensity significantly raises exports: a 0.1 unit increase in the import to sales ratio is associated with a 0.207 to 0.608 percent increase in exports of high-tech and low-tech firms in the scientific group, respectively, and a 0.424 percent increase in exports of low-tech firms in the non-scientific group. The most robust impact on export volumes comes from size, however, and for which every estimate in Tables 5a and 5b is significant and positive: a 1 percent increase in size (as measured by the capital stock) is associated with 0.81 to 1.10 percent and 0.82 to 0.90 percent increases in exports in the last set of estimates of Tables 5a and 5b, respectively. [22]

5. Concluding Remarks

We have used firm-level data from Indian manufacturing industries to examine the determinants of firms' exports. Our empirical analysis is based on a two-part estimation strategy whereby we first explore the factors which factors influence a firm's decision to enter the export market and then explore the factors, which influence the level of exports of firms, which decide to export.

Taken together, our results highlight several important features about the relationship between exports and various firm-level characteristics, especially those pertaining to technology. First, despite the fact that Indian manufacturing firms' investments in technical knowledge have been motivated by the compulsions of a large and protected domestic market they appear to have played a useful role in enabling firms to enter export markets, especially in the scientific group of industries where the scope for technological advances tend to be large and where design changes in both products and processes can be frequent.

Second, to the extent that investments in technical knowledge influence entry into export markets via their impact on quality and/or productivity, at least some of the positive association found between firms' productivity and their exporting status in the literature must be the result of more productive firms entering export markets. Of course, making formal investments in technical knowledge are by no means the only way in which firms improve productivity and thus the broad-based finding here that skill intensity is positively associated with participation in export markets bolsters the support for causality running from productivity to exporting (as in Clerides, Lach and Tybout, 1998).

---

influences positively the probability of exporting but not the volume of exports for exporting firms. However, it is difficult to see how an informational role would play out. More likely, the fact that at least the direction in which skill intensity affects export volumes is qualitatively similar to that found in the probit models suggests simply that skill intensity matters, but up to a point.

[22] How do our results compare with Kumar and Siddharthan (1994)? Despite the fact that there are a number of differences between our study and theirs', for example, in the approach to estimation, the level of aggregation, and the construction of variables, there are a number of common features between the two sets of results. For example, larger sales (their measure of size) and a lower capital to sales ratio (their measure of capital intensity) are generally associated with greater exports. These are similar to our results that firms with larger capital stocks and a lower capital to labor ratio have better export prospects. However, because their results are derived from a tobit model the distinction between entry into export markets and the export volumes of exporting firms is obscured. Thus when the imports of technology enter with a positive and negative sign across their estimates for various industries, for example, it is not too clear what drives this result. Similarly, the fact that Kumar and Siddharthan do not report the marginal effects of their tobit model makes it difficult to determine how important a factor is in driving exports.

Third, while investments in technical knowledge may have helped firms break into export markets via their impact on product quality and/or productivity other channels may also be operative. Recent econometric work by Roberts and Tybout (1997) confirms the case study evidence that entry into export markets can entail significant sunk costs and that an important source of these sunk costs are the informational requirements needed to serve a foreign market. Since investments in technology entail the establishment of foreign linkages, especially in the case of technology imports, they may help in overcoming the informational barriers surrounding entry into export markets.

Fourth, the differential impact of the import intensity of operations across the export participation and export volume models suggests to us that the imported inputs-exports link works through a positive effect of imported inputs on the quality of output of exporters. If imported inputs affected exports primarily through government regulations designed to encourage importers to earn foreign exchange by exporting, as has been suggested by some, then we would have expected to find firms with a larger dependence on imported inputs to participate in export markets more often.

Finally, the findings here that large size and a labor intensive production process can be important in improving export prospects for Indian manufacturing firms have continued relevance for the ongoing debate on India's reform efforts and the liberalization of trade and industrial policies that it has rested on.[23] Liberalization measures were expected to reduce the anti-export bias inherent in India's trade and industrial policies and spur Indian exports. In particular, reductions in protection along with an accompanying depreciation of the rupee were expected to increase the relative profitability of producing for the export markets while improved access to imported capital and intermediate goods would reduce production costs. Relaxation of restrictions on FDI and technology transfers through non-equity means (licensing, consultancy, etc.) were expected to improve the competitiveness of Indian products in export markets by upgrading product and process technologies and enabling firms to access international marketing networks.

Although it is difficult to say how much these various changes have contributed to export growth in the 1990s, the estimates obtained in this paper suggest that various liberalization measures, such as the relaxation of regulatory constraints on FDI and import of production inputs, should have improved the prospects for Indian exports.[24, 25] Nevertheless, certain regulatory policies may still be constraining Indian manufacturing exports. They may also be responsible for the continued domestic orientation of FDI in India (Kumar, 2000).

In particular, although the liberalization process which began in earnest in 1991 has alleviated many of the restrictions that industrial policy imposed on firm size, India continues to reserve certain labor intensive products exclusively for small-scale production.[26] Interestingly, some of these reserved

[23] While liberalization of India's trade and industrial policies had begun in the early 1980s, many of the most dramatic reform measures were undertaken in 1991. These included the abolishment of industrial and import licensing for most goods and restrictions on investments by large domestically owned firms, removal of non-tariff barriers on imports of intermediate and capital goods, the reduction of both tariff rates as well as their dispersion, and liberalization of policies toward FDI and technology transfer. Although there have been some minor reversals from time to time, there has been a clear trend toward greater liberalization throughout the 1990s. Thus, for example, average effective tariff rates declined from 42 percent in 1990 to around 28 percent in 1997 (World Bank, 1999). As in other countries, trade liberalization has been accompanied by a depreciation of the rupee.

[24] The average growth rate of exports averaged nearly 20% in dollar terms during 1993-94 to 1995-96. In comparison, export growth in 1996-97 and 1997-98 was only 5.3 and 4.6 percent, respectively, while exports declined by 3.9 percent in 1998-99 (Kumar, 2000).

[25] See Basant (2000) for a detailed discussion of Indian manufacturing firms' responses to the 1991 liberalization.

[26] Investment in the protected sectors cannot be more than ten million rupees (around $220,000).

products have included toys and garments – products in which other labor abundant countries such as China have achieved phenomenal export success. If size is an important factor in explaining exports, and the estimates here certainly lend strong support to this view, then the policy of reservation is likely to remain a drag on Indian exports. While there has been some progress – garments have recently been taken off the restricted list – the policy of reservation continues to remain in place.[27] Similarly, as per India's job security laws firms with more than 100 workers continue to require the explicit permission of the government to lay-off workers. A widely held belief among proponents of liberalization is that such laws have discouraged large-scale Indian firms from entering into labor intensive product markets.[28] If this is true, then the laws have restricted Indian exports in so far as this paper's estimates, which highlight the importance of size and labor intensity for exporting are concerned.

---

[27] As has been suggested by the recent Report of the Expert Committee on Small Enterprises (Government of India, 1997) the policy of reservation could be substituted by instruments that are promotional in nature.

[28] See, for example, Basu, Fields, and Debgupta (2000).

Appendix: 2SLS Estimates

In this appendix we carry out a robustness check on our OLS estimates of equation (2.2), the equation which describes the export volumes of exporting firms. In particular, we allow for the possibility that our stocks of technical knowledge, KRD and KMT, are endogenous and use instrumental variables (IV) to account for this endogeneity.[29] To serve as a valid instrument, a variable must be correlated with the potentially endogenous regressor and be uncorrelated with the error term of the export equation. Thus for our purposes we need variables, which are correlated with KRD and KMT but uncorrelated with the exports decision of the firm. Finding such variables is not easy. However, stocks of industry-wide "spillover" R&D should qualify. While the knowledge produced by a firm's R&D is usually considered to be non-rival and non-excludable and can benefit other firms, especially those in its industry, a firm will usually have to devote some resources towards its own R&D in order to derive spillover benefits from the R&D of others, (see Fikkert 1996 for evidence from India). Thus, the R&D of firms in the same industry should spur a firm's own R&D efforts. Alternatively, the larger the amount of other firms' R&D in any given industry, the more likely that a firm will need to perform R&D to remain competitive. Either way a larger stock of industry-wide R&D is likely to be correlated with own R&D. Yet there is no compelling reason for industry-wide R&D to be correlated with the exports of the individual firm.

While the argument regarding R&D spillovers make greatest sense for domestically conducted R&D, they could also apply to R&D conducted in other countries, such as the US.[30] Of course, the relevance of US R&D to Indian conditions is likely to vary across industries. For example, while the technical knowledge generated by R&D conducted in the US chemicals industry may be highly relevant to Indian chemical firms, the technical knowledge from R&D conducted in the US agricultural sector may not be. Therefore, it is necessary to adjust industry-wide US R&D spillovers for their relevance to Indian conditions. We use the index of relevance of US technology to Indian conditions constructed by Fikkert (1997) to weight industry wide R&D conducted in the US.

In addition to serving as an instrument for firms' stocks of R&D, US spillover R&D can also serve as an instrument for firms' stocks of imported technology since it is likely to be correlated with Indian firms' import of technology - although it is difficult to say a priori which way the relationship goes. On the one hand US spillover R&D can be viewed as representing a pool of potentially purchasable technical knowledge for Indian firms, in which case a larger stock of US spillover R&D should be positively correlated with Indian firms' purchase of imported technology. On the other hand, it is also possible that a larger pool of US technical knowledge may be subject to greater piracy by Indian firms, in which case we would expect US R&D spillovers to influence negatively Indian firms' purchase of imported technology but influence positively their own R&D as they attempt to "reverse engineer" the technology.[31] Of course, for our purposes here it does not matter which direction the relationship between US spillover R&D and imported technology runs in as long as there is one.

---

[29] As mentioned earlier, using an IV-type procedure in the first stage probit model is currently infeasible given the discontinuous nature of the technology stock variables.

[30] The United States is one of the largest suppliers of technology to Indian firms - between 1982 and 1986 the United States was the destination for a little less than half the total royalties remitted by Indian firms on account of technical collaborations (Reserve Bank of India, 1995).

[31] It is possible that Indian firms would be at a disadvantage in exporting in industries characterized by a high degree of technological opportunities - i.e. those with large R&D activity. This would have the result of rendering our US spillover stocks invalid as an instrument (the instrument would be negatively correlated with the error term of the exporting equation ,). However, in the first place more technology intensive industries are not characterized by lower exports in our sample. Secondly, it is unlikely that Indian firms compete with technological leaders such as the US in export markets in any case.

The stocks of domestic and US spillover R&D are constructed in the same manner as firms' stocks of own R&D and imported technology. That is, R&D expenditure data for Indian (Department of Science and Technology, 1992) and US industries (National Science Foundation, online data base) from 1989 to 1991 are first deflated using the technology expenditures deflator described earlier and then aggregated using equation (3.1) above to arrive at industry level R&D stocks.[32] The domestic spillover variable is then computed by subtracting each firm's R&D from the industry-wide figure. While this last step is not required for the US industry wide figures, it is necessary to weight the US figures by Fikkert's index of technology relevance computed as the ratio of US patents in industry j taken out in India to the total number of US patents in industry j between the years 1972-1989 (see Fikkert 1997 for further details and comparison of this measure with other measures of technology relevance across countries).

The resulting IV estimates are detailed in Table A1.[33] For the scientific and non-scientific groups as a whole the IV estimates are broadly similar to the corresponding OLS estimates in Tables 5a and 5b. The only differences are that significant coefficients on capital intensity in the OLS estimates for the scientific group and on KMT in the OLS estimates for the non-scientific group become insignificant. Their signs remain the same, however, as is also the case for all other variables. Unfortunately, the IV estimates for the high-tech subgroups are estimated rather imprecisely with none of the coefficients being statistically significant at even the 10 percent level. The most likely reason for this is that the instruments do a poor job in adding to the predictive power of the first stage regressions for KRD and KMT in the high-tech subgroups. While the adjusted R^2 of the first stage regressions for KRD and KMT are 0.28 and 0.29, respectively, in the scientific group and 0.22 and 0.35, respectively, in the non-scientific group, these become 0.22 and 0.29, respectively, in the scientific group and 0.18 and 0.15, respectively, in the non-scientific group when only the high-tech subgroup is considered. Apparently, the exclusion of firms which have zero amounts of KRD and KMT (the defining characteristic of high-tech subgroups is the presence of investments in formal technical knowledge) reduces the amount of overall variation in KRD and KMT that there is to explain thereby making the task of our instruments more demanding. While the unavailability of better instruments for the high-tech subgroups is disappointing we find the fact that the IV estimates for the scientific and non-scientific groups as a whole are qualitatively similar to our OLS estimates reassuring.

[32] The US R&D figures are first converted into Rupees using the US Dollar-Rupees exchange rate.

[33] Results for the estimates based on dummy variable measures of FDI are qualitatively similar in nature and not reported.

References

Aiken, B., G. H. Hanson, and A.E. Harrison, "Spillovers, Foreign Investment, and Export Behavior," *Journal of International Economics*, 43 (1997): 103-132.

Alam, G., *Research and Development by Indian Industry: A Study of the Determinants of Its Size and Shape*, Center for Technology Studies, New Delhi, 1994.

Arora, A., "Contracting for Tacit Knowledge: The Provision of Technical Services in Technology Licensing Contracts," *Journal of Development Economics*, 50 (1996): 233-256.

Aw, B.Y. and G. Batra, "Technology, Exports and Firm Efficiency in Taiwanese Manufacturing," *Economics of Innovation and New Technology*, 1998.

Aw, B.Y. and A.R. Hwang, "Productivity and the Export Market: A Firm Level Analysis," *Journal of Development Economics*, 47 (1995): 313-332.

Basant, R., "Corporate Response to Economic Reforms," *Economic and Political Weekly*, March 4 (2000): 813-822.

Basant, R. and B. Fikkert, "The Effects of R&D, Foreign Technology Purchase, and International and Domestic Spillovers on Productivity in Indian Firms," *The Review of Economics and Statistics*, 78:2 (1996): 187-199.

Basu, K, G. Fields, and S. Debgupta, "Alternative Labor Retrenchment Laws and their Effect on Wages and Employment: A Theoretical Investigation with Special Reference to Developing Countries," Center for Analytic Economics Working paper #00-11, Department of Economics, Cornell University, 2000.

Bell, M. and D. Scott-Kemmis, "Technology Import Policy: Have the Problems Changed?" *Economic and Political Weekly*, 20, Special Number, November, (1985).

Berry, R.A., "Firm Size in the Analysis of Trade and Development" in G. Helleiner (ed.) *Trade Policy, Industrialization, and Development,* Oxford: Clarendon Press, 1992.

Central Statistical Organization, *Annual Survey of Industries: Summary Results for the Factory Sector*, Ministry of Planning, Government of India, published annually.

Chandhok, H. L., *India Database: The Economy, Volumes I-II,* The Policy Group, 1991.

Chen, T and D. Tang, "Comparing Technical Efficiency Between Import-Substitution-Oriented and Export-Oriented Foreign Firms in a Developing Economy," *Journal of Development Economics*, 26, (1987): 277-289.

Clerides, S., S. Lach and J. Tybout, "Is 'Learning-by-Exporting' Important? Micro-dynamic Evidence from Colombia, Mexico and Morocco," *Quarterly Journal of Economic,* (1998): 903-947.

Department of Science and Technology, *Research and Development in Industry*, Ministry of Science and Technology, Government of India, New Delhi, published annually.

Department of Scientific and Industrial Research, *Compendium on In-House R&D Centers*, Ministry of Science and Technology, Government of India, New Delhi, published annually.

Desai, A., "Indigenous and Foreign Determinants of Technological Change in Indian Industry," *Economic and Political Weekly*, 20, Special Number, November, (1985)

Duan, N., W. G. Manning, Jr., C. Morris, and J. P. Newhouse, "Choosing Between the Sample-Selection Model and the Multi-Part Model," *Journal of Business and Economic Statistics*, 2, No. 3, (1984): 283-289.

Evenson, R. and L. Westphal, "Technological Change and Technology Strategy," in J. Behrman and T.N. Srinivasan (ed.) *Handbook of Development Economics, Volume III*, Elsevier Science, 1995, pp. 2211-2299.

Fikkert, B., "Application of the Yale Technology Concordance to the Construction of International Spillover Variables in India'" *Economic Systems Research*, 9, No. 2, (1997): 193-203.

Fikkert, B., "An Open or Closed Technology Policy? The Impacts of International Knowledge Diffusion on Self-Reliance and Productivity in Less Developed Countries," Working paper at the University of Maryland, 1996.

Government of India, *Report of the Expert Committee on Small Enterprises*, New Delhi, (1997).

Greene, W., 1995, *User's Manual for Limdep, Version 7*. Econometric Software.

Griliches, Z. and J. Mairesse, "Productivity and R&D at the Firm Level," in Z. Griliches (ed.) *R&D, Patents and Productivity*, University of Chicago Press, 1984, pp. 339-374.

Hay, J. W. and R. Olsen, "Let Them Eat Cake: A Note on Comparing Alternative Models of the Demand for Medical Care," *Journal of Business and Economic Statistics*, 2, No. 3, (1984): 279-282.

Kumar, N., "Economic Reforms and Their Macro-Economic Impact," *Economic and Political Weekly*, March 4 (2000): 803-812.

Kumar, N. and N.S. Siddharthan, "Technology, Firm Size and Export Behavior in Developing Countries: The Case of Indian Enterprises," *The Journal of Development Studies*, 31, No. 2, (1994): 289-309.

Lall, S, *Learning to Industrialize.* London: The Macmillan Press, 1987.

Lin T.F and P. Schmidt, "A Test of the Tobit Specification Against an Alternative Suggested by Cragg," (1983):174-177.

Reserve Bank of India, *Reserve Bank of India Bulletin*, Government of India, 1995.

Rivers, D. and Q. H. Vuong, "Limited Information Estimators and Exogeneity Tests for Simultaneous Probit Models," *Journal of Econometrics*, 39, (1988): 347-366.

Roberts, M. and J. Tybout, "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs," *American Economic Review*, 87:4, (1997): 545-563.

Tybout, J. and M. Westbrook, "Trade Liberalization and the Dimensions of Efficiency Change in Mexican Manufacturing Industries," *Journal of International Economics*, 39, (1995): 53-78.

Vakil, T., *Achieving Excellence: Case Studies of Entrepreneurship and Export Successes of Six Indian Companies*, The Exim Bank of India, Tata McGraw-Hill Publishing Co. Ltd., 1996.

World Bank, *The East Asian Miracle: Economic Growth and Public Policy*, Oxford University Press for the World Bank, Washington, DC, 1993.

World Bank, *Knowledge for Development*, World Development Report, Washington DC, 1998.

World Bank, *World Development Indicators*, Washington DC, 1999.

Table 1
Basic Statistics

Industry	Firms	Exports[a] (Rs. 1,000)	Exporters (% Firms)	KRD[a] (Rs. 1,000)	KRD>0 (% Firms)	KMT[a] (Rs. 1,000)	KMT>0 (% Firms)	FDI (% Firms)	Net Sales[a] (Rs. 1,000)	TGFA[a] (Rs. 1,000)
Non-Scientific	**316**	**36,070**	**57**	**2,057**	**27**	**2,332**	**20**	**24**	**681,514**	**500,112**
Food Processing	49	36,941	43	2,072	37	1,892	16	29	703,121	329,741
Cotton Textiles	86	65,021	63	522	10	4,925	6	13	678,679	598,913
Other Textiles	26	53,110	73	1,001	19	296	8	27	753,268	502,540
Paper Products	32	5,132	38	703	31	864	28	16	579,804	466,510
Non-Metallic Mineral Products	40	14,175	68	7,124	50	2,701	43	45	950,089	904,757
Metal Products	83	22,701	54	2,052	29	931	27	24	558,999	315,506
Scientific	**369**	**63,522**	**73**	**16,015**	**55**	**6,793**	**52**	**53**	**1,003,892**	**630,545**
Rubber Products	24	96,519	88	8,461	33	10,163	50	42	1,189,497	724,024
Chemical Products	150	64,814	76	18,127	67	7,338	38	58	1,051,199	844,772
Non-Electrical Machinery	88	59,863	77	7,172	36	6,621	68	55	656,579	325,106
Electrical Machinery	69	43,205	59	14,423	59	3,884	57	51	785,014	284,919
Transport Equipment	38	82,942	71	35,817	58	8,192	61	45	1,901,667	1,060,788

Notes: [a] Numbers are simple averages pertaining to the row-specific sub-sample. TGFA refers to total gross fixed assets.

Table 2a
Basic Statistics by Group and Market Orientation

Group	Firms	Exports[a] (Rs. 1000)	Exports/ Net Sales[a]	KRD[a] (Rs. 1000)	KRD>0 (% Firms)	KTP[a] (Rs. 1000)	KTP>0 (% Firms)	FDI (% Firms)	Skill Intensity[a]	Import Intensity[a]	TGFA/ Wage-Bill[a]	Net Sales[a] (Rs. 1000)	TGFA[a] (Rs. 1000)
Non-Scientific													
Exports=0	138	0	0	1,004	25	409	14	12	0.04	0.06	19	404,327	293,785
Exports>0	178	64,035	0.08	2,875	29	3,823	25	33	0.07	0.08	8	896,412	660,073
Scientific													
Exports=0	98	0	0	1,201	35	2,455	35	32	0.07	0.12	10	271,993	284,906
Exports>0	271	86,492	0.08	21,372	62	8,362	58	61	0.14	0.14	8	1,268,563	755,536

Notes: [a] Numbers are simple averages pertaining to the row-specific sub-sample. TGFA refers to total gross fixed assets.

Table 2b
Basic Statistics By Group And Stocks Of Technical Knowledge

Group	Firms	Exporters (% Firms)	Exports[a] (Rs. 1000)	Exports/ Net Sales[a] (%)	KRD[a] (Rs. 1000)	KMT[a] (Rs. 1000)	FDI (% Firms)	Skill Intensity[a]	Import Intensity[a]	TGFA/ Wage Bill[a]	Net Sales[a] (Rs. 1000)	TGFA[a] (Rs. 1000)
Non-Scientific												
KRD,KMT=0	197	53	31,900	0.05	0	0	13	0.04	0.05	14	459,224	282,143
KRD or KMT>0	119	62	42,973	0.04	5,464	6,193	42	0.08	0.10	12	1,049,507	860,951
Scientific												
KRD,KMT=0	96	57	22,489	0.06	0	0	28	0.09	0.13	8	295,154	126,584
KRD or KMT>0	273	79	77,951	0.06	21,647	9,182	62	0.13	0.14	9	1,253,118	807,762

Notes: [a] Numbers are simple averages pertaining to the row-specific sub-sample. TGFA refers to total gross fixed assets.

Table 3a
Probit Model for Export Participation: Scientific Firms

	Foreign Equity Dummy			Foreign Equity>20% Dummy			Foreign/Total Equity		
	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms
Constant	-6.53**	-7.47**	-9.58**	-6.59**	-7.57**	-9.47**	-6.45**	-7.37**	-9.91**
	(-4.67)	(-3.78)	(-3.63)	(-4.63)	(-3.74)	(-3.51)	(-4.57)	(-3.71)	(-3.53)
Ln(KRD)	0.03**	0.06**	-	0.03**	0.06**	-	0.03**	0.06**	-
	(2.56)	(3.24)	-	(2.59)	(3.31)	-	(2.66)	(3.30)	-
Ln(KMT)	0.01	0.05**	-	0.001	0.04**	-	0.003	0.04**	-
	(0.39)	(2.46)	-	(0.06)	(2.22)	-	(0.19)	(2.32)	-
FDI	0.16	-0.07	1.07**	0.69**	0.62**	1.68**	1.25**	0.98*	5.67**
	(0.90)	(-0.29)	(2.57)	(3.26)	(2.57)	(2.52)	(2.49)	(1.70)	(2.89)
Skill Intensity	3.86**	3.25**	6.07**	3.65**	2.66*	7.91**	3.67**	2.76**	8.07**
	(3.43)	(2.39)	(2.57)	(3.21)	(1.91)	(3.26)	(3.26)	(2.03)	(3.27)
Ln(K/L)	-0.54**	-0.75**	-0.32	-0.52**	-0.70**	-0.40**	-0.52**	-0.71**	-0.35*
	(-4.56)	(-4.53)	(-1.62)	(-4.32)	(-4.13)	(-1.98)	(-4.32)	(-4.23)	(-1.71)
Import Intensity	0.53	0.44	0.89	0.51	0.36	0.83	0.50	0.33	0.92
	(1.12)	(0.62)	(1.38)	(1.07)	(0.50)	(1.25)	(1.05)	(0.47)	(1.37)
Ln(Size)	0.43**	0.45**	0.58**	0.43**	0.45**	0.58**	0.42**	0.44**	0.60**
	(5.44)	(4.22)	(3.87)	(5.38)	(4.06)	(3.78)	(5.31)	(4.05)	(3.75)
Log Likelihood Function	-152.07	-95.62	-40.63	-146.76	-92.16	-39.88	-149.20	-94.18	-37.96
N	369	273	96	369	273	96	369	273	96

Notes. Industry dummies included in all regressions. T-statistics are in parenthesis. **Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level.

Table 3b
Probit Model for Export Participation: Non-Scientific Firms

	Foreign Equity Dummy			Foreign Equity>20% Dummy			Foreign/Total Equity		
	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms
Constant	-4.65**	-1.29	-7.14**	-5.19**	-1.84	-7.48**	-5.04**	-1.59	-7.43**
	(-3.16)	(-0.47)	(-3.72)	(-3.58)	(-0.68)	(-3.95)	(-3.48)	(-0.59)	(-3.92)
Ln(KRD)	-0.01	0.01	-	-0.01	0.03	-	-0.01	0.03	-
	(-0.76)	(0.54)	-	(-0.45)	(1.28)	-	(-0.61)	(1.16)	-
Ln(KMT)	0.01	0.03	-	0.01	0.04*	-	0.01	0.04*	-
	(0.34)	(1.06)	-	(0.52)	(1.67)	-	(0.56)	(1.69)	-
FDI	0.54**	0.76**	0.31	1.00**	1.33**	0.58	2.62**	3.13**	1.81
	(2.51)	(2.57)	(0.92)	(2.80)	(2.68)	(0.97)	(2.70)	(2.54)	(0.98)
Skill Intensity	4.95**	4.64*	6.63**	4.75**	3.98*	6.64**	4.65**	3.93	6.55**
	(2.56)	(1.80)	(2.32)	(2.42)	(1.64)	(2.32)	(2.37)	(1.62)	(2.28)
Ln(K/L)	-0.35**	-0.42**	-0.25	-0.33**	-0.33	-0.26*	-0.32**	-0.30	-0.25
	(-2.85)	(-1.98)	(-1.59)	(-2.67)	(-1.54)	(-1.67)	(-2.55)	(-1.38)	(-1.62)
Import Intensity	0.19	0.65	-0.03	-0.06	-0.10	-0.02	-0.09	-0.08	-0.02
	(0.24)	(0.55)	(-0.02)	(-0.07)	(-0.09)	(-0.01)	(-0.12)	(-0.07)	(-0.02)
Ln(Size)	0.25**	0.06	0.37**	0.28**	0.07	0.39**	0.27**	0.05	0.39**
	(2.98)	(0.37)	(3.44)	(3.39)	(0.45)	(3.72)	(3.27)	(0.35)	(3.69)
Log Likelihood Function	-185.53	-62.60	-113.95	-184.24	-61.43	-113.89	-184.27	-61.94	-113.85
N	316	119	197	316	119	197	316	119	197

Notes. Industry dummies included in all regressions. T-statistics are in parenthesis. **Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level.

Table 4:
Marginal Effects from Probit Models

	Scientific Firms			Non-Scientific Firms		
	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms
Constant	-1.65**	-1.39**	-3.44**	-1.97**	-0.58	-2.95**
	(-4.43)	(-3.52)	(-3.55)	(-3.47)	(-0.59)	(-3.92)
Ln(KRD)	0.008**	0.011**	-	-0.003	0.010	-
	(2.71)	(3.35)	-	(-0.61)	(1.16)	-
Ln(KMT)	0.001	0.008**	-	0.004	0.015*	-
	(0.19)	(2.30)	-	(0.56)	(1.68)	-
Foreign/ Total Equity	0.32**	0.18*	1.97**	1.02**	1.14**	0.72
	(2.52)	(1.70)	(3.25)	(2.72)	(2.61)	(0.98)
Skill Intensity	0.94**	0.52**	2.80**	1.81**	1.43*	2.60**
	(3.51)	(2.20)	(3.49)	(2.38)	(1.64)	(2.28)
Ln(K/L)	-0.13**	-0.13**	-0.12*	-0.12**	-0.11	-0.10
	(-4.37)	(-4.06)	(-1.73)	(-2.54)	(-1.38)	(-1.62)
Import Intensity	0.13	0.06	0.32	-0.04	-0.03	-0.01
	(1.05)	(0.47)	(1.39)	(-0.12)	(-0.07)	(-0.02)
Ln(Size)	0.11**	0.08**	0.21**	0.10**	0.02	0.15**
	(5.19)	(3.83)	(3.82)	(3.27)	(0.35)	(3.69)

Notes: Marginal effects have been computed at the overall means of the relevant data. Industry dummies included in all regressions. T-statistics are in parenthesis and are computed using the delta method.
**Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level.

Table 5a
OLS for Exporting Firms: Scientific Firms

	Foreign Equity Dummy			Foreign Equity>20% Dummy			Foreign/Total Equity		
	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms
Constant	-3.19	-3.54	-0.76	-3.55*	-4.17*	-1.14	-3.32*	-3.86*	-0.98
	(-1.63)	(-1.49)	(-0.17)	(-1.89)	(-1.89)	(-0.28)	(-1.74)	(-1.73)	(-0.24)
Ln(KRD)	0.01	0.01	-	0.01	0.01	-	0.01	0.01	-
	(0.75)	(0.46)	-	(0.66)	(0.61)	-	(0.82)	(0.67)	-
Ln(KMT)	-0.01	-0.01	-	-0.01	-0.01	-	-0.01	-0.01	-
	(-0.38)	(-0.46)	-	(-0.59)	(-0.41)	-	(-0.65)	(-0.52)	-
FDI	0.12	0.21	-0.07	0.63**	0.63**	0.38	1.42**	1.57**	0.41
	(0.51)	(0.86)	(-0.11)	(3.08)	(2.87)	(0.64)	(2.89)	(2.96)	(0.32)
Skill Intensity	0.91	0.59	1.64	0.31	0.03	1.34	0.32	-0.05	1.49
	(1.31)	(0.83)	(0.72)	(0.47)	(0.04)	(0.65)	(0.49)	(-0.07)	(0.69)
Ln(K/L)	-0.50**	-0.67**	-0.23	-0.44**	-0.61**	-0.19	-0.43**	-0.59**	-0.21
	(-3.46)	(-3.69)	(-0.97)	(-3.10)	(-3.41)	(-0.91)	(-2.97)	(-3.25)	(-0.94)
Import Intensity	3.11**	1.92	6.07**	3.12**	2.06*	5.98**	3.18**	2.07*	6.08**
	(3.43)	(1.62)	(3.72)	(3.57)	(1.80)	(3.71)	(3.62)	(1.80)	(3.71)
Ln(Size)	1.03**	1.10**	0.80**	1.04**	1.12**	0.82**	1.03**	1.10**	0.81**
	(9.42)	(8.53)	(3.36)	(9.99)	(9.38)	(3.67)	(9.69)	(9.08)	(3.58)
Adjusted R-squared	0.36	0.36	0.20	0.38	0.38	0.21	0.38	0.38	0.21
N	271	216	55	271	216	55	271	216	55

Notes. Dependent variable is Ln(Exports). Industry dummies included in all regressions. T-statistics are in parenthesis and are based on heteroskedastic consistent standard errors. **Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level.

Table 5b
OLS for Exporting Firms: Non-Scientific Firms

	Foreign Equity Dummy			Foreign Equity>20% Dummy			Foreign/Total Equity		
	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms	All Firms	High-Tech Firms	Low-Tech Firms
Constant	0.76	1.92	-0.41	1.26	2.39	0.29	0.96	1.88	0.20
	(0.27)	(0.38)	(-0.12)	(0.46)	(0.49)	(0.09)	(0.35)	(0.39)	(0.06)
Ln(KRD)	0.02	0.05	-	0.02	0.04	-	0.02	0.05	-
	(0.73)	(1.26)	-	(0.79)	(1.06)	-	(0.83)	(1.10)	-
Ln(KMT)	-0.07**	-0.01	-	-0.07**	-0.03	-	-0.07**	-0.03	-
	(-2.10)	(-0.31)	-	(-2.42)	(-0.71)	-	(-2.50)	(-0.73)	-
FDI	-0.31	-0.34	-0.43	-0.93**	-0.80	-0.82	-1.87	-1.73	-1.58
	(-1.02)	(-0.65)	(-1.19)	(-2.03)	(-1.40)	(-1.63)	(-1.49)	(-1.09)	(-1.20)
Skill Intensity	2.78	2.57	6.16	3.11	2.56	6.35	3.08	2.54	6.32
	(1.26)	(0.94)	(1.48)	(1.32)	(0.88)	(1.51)	(1.32)	(0.88)	(1.50)
Ln(K/L)	-0.36	-0.70*	-0.33	-0.39	-0.72**	-0.29	-0.40	-0.76**	-0.28
	(-1.45)	(-1.94)	(-0.86)	(-1.60)	(-2.00)	(-0.80)	(-1.61)	(-2.13)	(-0.77)
Import Intensity	1.77	0.31	4.37*	2.05	0.70	4.19*	1.98	0.56	4.24*
	(1.16)	(0.16)	(1.79)	(1.46)	(0.38)	(1.77)	(1.37)	(0.30)	(1.79)
Ln(Size)	0.88**	0.80**	0.94**	0.86**	0.79**	0.89**	0.87**	0.82**	0.90**
	(5.44)	(2.78)	(4.62)	(5.53)	(2.83)	(4.67)	(5.60)	(2.93)	(4.66)
Adjusted R-squared	0.30	0.24	0.33	0.32	0.25	0.33	0.31	0.25	0.33
N	178	74	104	178	74	104	178	74	104

Notes. Dependent variable is Ln(Exports). Industry dummies included in all regressions. T-statistics are in parenthesis and are based on heteroskedastic consistent standard errors. **Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level.

Table A1
2SLS Model for Exporting Firms

	Scientific Firms		Non-Scientific Firms	
	All Firms	High-Tech Firms	All Firms	High-Tech Firms
Constant	-3.05	-19.89	-2.38	5.68
	(-0.45)	(-0.39)	(-0.23)	(0.35)
Ln(KRD)	0.08	-0.48	0.41	0.39
	(0.60)	(-0.26)	(1.01)	(1.46)
Ln(KMT)	-0.09	-0.30	-0.75	-0.29
	(-1.39)	(-0.76)	(-1.05)	(-0.41)
Foreign/Total Equity	1.77**	0.30	-6.01	-4.28
	(2.92)	(0.05)	(-1.10)	(-0.75)
Skill Intensity	0.05	0.13	25.88	19.57
	(0.07)	(0.05)	(1.12)	(1.15)
Ln(K/L)	-0.24	-1.46	-0.13	-0.33
	(-0.66)	(-0.34)	(-0.21)	(-0.27)
Import Intensity	3.42**	2.31	6.42	4.68
	(3.78)	(0.59)	(0.92)	(0.73)
Ln(Size)	1.01**	2.43	0.97*	0.44
	(2.42)	(0.59)	(1.74)	(0.43)
N	271	216	178	74

Notes. Dependent variable is Ln(Exports). Industry dummies included in all regressions. T-statistics are in parenthesis and are based on heteroskedastic consistent standard errors. **Statistically significant at the 5 percent level; *Statistically significant at the 10 percent level. Instrument list for both KRD and KMT consists of domestic and US spillover R&D stocks, an index of technological relevance of US R&D for Indian industry, an interaction term between US spillover R&D stocks and the index of relevance, and all exogenous right hand side variables of the second stage regression equation. Adjusted R^2 s are not bounded between 0 and 1 and are not reported.