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REVISITING THE R&D-PRODUCTIVITY LINKAGE AND EXPORT-LED GROWTH HYPOTHESIS: AN EMPIRICAL STUDY ON EXPORTING MANUFACTURERS IN CHINA

Xiaolin Li, Towson University
Abey Kuruvilla, University of Wisconsin-Parkside
Yanhua Liu, Wuhan College of Economics and Management
Suvankar Ghosh, Kent State University

The R&D-productivity linkage and export-led growth hypothesis are among the most debated issues pertaining to business productivity. Synthesizing findings of extant studies on factors affecting business performance, this paper formulates a framework on the relationship between R&D, export, firm size, industry, and business productivity. General linear modeling on cross-sectional data of 270 exporting manufacturers (EMs) in China validates the R&D-productivity linkage. The study also finds a significant effect of firm size and industry on productivity. But no evidence is found for the controversial export-led growth hypothesis.

Introduction

The R&D-productivity linkage and export-led growth hypothesis are among the most debated issues pertaining to business performance. As the most prevalent form of international expansion (Salomon and Shaver, 2005), export enables a firm to access diverse knowledge unavailable in the domestic market; such knowledge may spill back and further foster learning and productivity (Marin, 1992; Salomon and Shaver, 2005).

Exporters are also more exposed to global markets' calls for efficiency and innovation (Marin, 1992). In particular, exporting may provide firms in less developed economies with opportunities to learn from more advanced economies, which in turn, spur these firms' productivity and overall economic growth (Yasar, Garcia, Nelson, and Rejesus, 2007). However, research on the relationship between export and business performance has yielded inconsistent results (Mahadevan, 2007). The export-led growth hypothesis, therefore, remains a controversial issue.

Research and development (R&D) is another widely recognized source of productivity growth (Rouvinen, 2002). R&D is believed to not only stimulate innovation, but also enhance technology transfer--facilitating the imitation of others' technology discoveries (Griffith, Redding, and Reenen, 2004). As a result, firms that have higher commitment to R&D tend to do better on product market and achieve higher labor productivity and growth than those that do not (Mont and Papagni, 2003).

Nevertheless, some recent studies (e.g., Mansury and Love, 2008) show no evidence that innovation has a significant effect on productivity. Skepticism in the R&D-productivity relationship has also arisen among some researchers (e.g., Braun et al, 2005), who believe that, through R&D outsourcing and alliances, a firm can achieve a desirable business performance without developing innovative capabilities of its own.

Additionally, business leaders' confidence in R&D appears to have decreased. According to an IBM global survey of Chief Executive Officers (CEOs), only 17 percent of the 765 CEOs surveyed mentioned R&D in their list of sources of business performance. In fact, R&D was ranked eighth among their main sources, well behind trading partners, customers, and even competitors; less than 3 percent of the global CEOs considered their R&D managers capable of leading enterprise-wide business innovations (Radjou & Wolff, 2006).

Does export actually have an effect on a firm's productivity? Does R&D truly matter in a firm's productivity improvement? Is firm size associated with productivity? A great deal of research has been conducted to pursue answers to these questions. But these issues remain controversial. Prior studies mostly focus on individual issues. A more holistic model that unifies extensively debated major factors of productivity is lacking. Using cross-sectional data of 270 exporting manufacturers in China, this study reexamines, at the firm level, three major sources of business productivity--export, innovation, and firm size. Findings of the study may enhance understanding in productivity, business performance, and overall competitiveness of exporting manufacturers.

The remainder of the paper is arranged as follows: Section 2 reviews the literature and formulates a research model and associated hypotheses. Section 3 discusses the research methods used, which include variables and their measurement, data collection mechanisms, sample, and statistical method. Section 4 reports the major findings of the study. Section 5 concludes the paper with a discussion on implications, future research, and limitations of the study.

Theory Development and Research Hypotheses

Innovation-Productivity Link

Innovation is increasingly regarded as an important contributor to business performance and competitive advantage (O'Regan, Ghobadian, and Sims, 2006; Zahra, Nielsen, and Bognar, 1999). Innovation activities impact productivity by increasing efficiency and output volume, improving product quality and reducing labor inputs (Pianta, 2001). Such impact is reflected both at the firm and industry levels (Pianta and Vaona, 2007). Innovation is found to be positively correlated with productivity even when controlling for physical capacity and workers' skills (Crépon, Duguet, and Mairesse, 1998). Research (Bobillo, Sanz, & Gaite, 2006) has also demonstrated that innovation plays a crucial role in the sustainability of a firm's productivity.

R&D is a widely recognized innovation activity that enhances productivity growth (Crépon, Duguet, and Mairesse, 1998; Masso and Vahter, 2008; Rouvinen, 2002). A large body of literature has demonstrated R&D to be positively associated with business productivity. For instance, Rouvinen (2002) suggests there is a Granger causal relationship between R&D and firm productivity. Aw, Roberts, and Xu (2008) find that R&D investment affects a firm's future productivity, which in turn, increases the long-term return on R&D investments. Knott, Bryce, and Posen (2003) suggest that R&D as an asset of a firm can be accumulated, and the accumulated stock of such assets constitutes an important factor in the firm's productivity.

China is known for its labor-intensive manufacturing industry. In recent decades, however, China has increased its efforts and investment in R&D, in the hope of transforming its economy to a more technologically based one. For example, between 1995 and 1999, China's R&D expenditure as the percentage of sales increased from 0.4% to 0.8% and its R&D personnel as the percentage of total employees rose from 3.4% to 7.3% (Jefferson et al., 2006). In the long run, China's ability to innovate, to absorb and to diffuse new technologies, and eventually to become a leading contributor of industrial knowledge will play an increasing role in its economic performance (Jefferson, Bai, Guan, and Yu, 2006).

China's increased return on investment in R&D is particularly high—at least three or four times the return to fixed production assets (Jefferson et al., 2006). R&D efforts of enterprises in China have boosted their productivity. For instance, Hu (2001) has examined the relationship between R&D expenditure and productivity in China's enterprises and has found a strong, direct link between privately funded R&D and firm productivity. Fisher-Vanden and Wing (2008) have also suggested that China's increasing input in R&D is contributing substantially to its productivity improvement.

Based on the above, we hypothesize:

Hypothesis 1: An exporting manufacturer (EM)'s innovation intensity is positively associated with its productivity.

Export-Led Productivity Growth

Export-led growth hypothesis is among the most debated issues related to the impact of exports on business performance. The hypothesis suggests that exporting is positively associated with business performance and such correlation is the result of the absorption of knowledge and technologies during the exporting process (Alvarez and López, 2005).

A few commonly cited arguments for the export-led growth hypothesis include: First, exports increase economy of scale—incorporating the global market naturally increases the scale of business operations—which in turn, improves productivity (Baldwin and Gu 2004; Kunst and Marin, 1989). Secondly, exporters face stronger pressure from global competition to innovate and to improve productivity (Baldwin and Gu 2004; Kunst and Marin, 1989). Thirdly, learning by exporting—exporters learn from companies in other countries, particularly more developed countries, and improve their productivity (Baldwin and Gu, 2004).

Some prior studies have demonstrated exporting to be an important factor underlying productivity improvement. Salomon and Shaver (2005) conducted a study on Spanish manufacturing firms from 1990 to 1997 and found strong evidence for the export-led growth hypothesis. Alvarez and López (2005) provided plant-level evidence for export-led growth from Chile. Trofimenko (2008) conducted an empirical study on Colombian manufacturing firms between 1981 and 1991 and found that facilitating access to developed markets improved a firm's productivity.

Case studies by Crespi, Criscuolo, and Haskel (2008) found that exporting firms learned more from clients and were more likely to improve their productivity. Van Biesebroeck (2005) found that manufacturing exporters in subSaharan African countries were more productive and they increased their productivity advantage after entering the export market, even when self-selection into the export market were controlled for.

Some studies in developed countries also found evidence for the export-led growth hypothesis. Marin (1992) studied the relationship between export and productivity in four industrialized countries including Germany, United Kingdom, United States, and Japan, and found the exports Granger-cause productivity in those countries. Awokuse's study (2006) on Japanese firms revealed bi-directional causal relationship between exporting and economic growth.

However, some have questioned export-led growth hypothesis. They argue that the possible correlation between export intensity and growth may be the result of self-selection—efficient and productive firms tend to choose to be exporters (Alvarez and López, 2008; Clerides, Lach, Tybout, 1998; Greenaway and Kneller, 2004). Some empirical studies have found little or no support for the export-led growth hypothesis. For instance, Wagnera (2002) found very little support for the positive effect of export on labor productivity. Bernard and Jensen (1999) failed to find any evidence for export-led growth hypothesis.

China is an ideal setting for testing the export-led growth hypothesis in that: 1) it is an export-driven economy, and 2) it is less technologically advanced than many of the countries it exports to, and thus, has a high potential to learn from those countries. Although research on export and productivity in China is scarce, some research has found support for the hypothesis. For example, Perkins (1997) found that exporters in China had a higher total factor productivity growth than non-exporters and he suggested that China would gain significant economic growth by encouraging exporting, which in turn, would enhance its productivity.

Based on the discussion above, we hypothesize:

Hypothesis 2*:* An exporting manufacturer's export intensity is positively associated with its productivity.

Firm Size and Productivity

The debate about the relationship between firm size, R&D, and productivity has been heated since the development of "Schumpeterian Hypothesis" (Schumpeter, 1934), which suggests that firm size is positively associated with innovation productivity—the larger the firm, the higher the return from its R&D investment.

Differing and often contradictory points of views have been offered toward the hypothesis. Some researchers support the Schumpeterian Hypothesis by arguing that R&D enhances productivity more in larger firms because of the synergy between R&D and other complementary capabilities of larger firms (Cohen, 1995; Griffin and Hauser, 1996) and the advantages of cost spreading—larger firms spread the costs of R&D over a larger number of outputs, and thus, gain higher per-unit return of R&D (Cohen and Klepper, 1996). But others argue that the hypothesis may not hold because of the loss of efficiency among larger firms in R&D resulting from the lack of marginal control or from excessive bureaucratic control which diverts the attention of the firms' technologists (Scherer and Ross, 1990).

Still others developed competing theories to the Schumpeterian Hypothesis. For instance, Pavitt, Robson, Townsend (1987) developed a 'U-type' framework on the relationship between R&D performance and firm size, which suggested that R&D was more productive both in small and large firms than in medium-sized firms. Such 'U-type' relationship between R&D productivity and firm size was validated by a more recent study (Tsai and Wang, 2005). Empirical evidence reported in literature is mixed as well. While most studies (Link, 1981; Lichtenberg and Siegel, 1991) have validated the Schumpeterian Hypothesis by revealing a positive relationship between R&D returns and firm size, others have invalidated the hypothesis by finding no relationship (Jensen, 1987) or opposite or different relationships between firm size and return on R&D (Acs and Audretsch, 1990, 1991; Graves and Langowitz, 1993; Griliches, 1980; Scherer and Ross, 1990).

Schumpeterian Hypothesis remains a controversy and further empirical evidence is needed in order to better understand the relationship between R&D productivity and firm size. Given that, we would test the following hypothesis:

Hypothesis 3*:* An exporting manufacturer's firm size is positively associated with its business productivity.

Industry and Productivity

Industry is likely to affect the extent to which innovation impacts economic performance because the requirement for R&D resources across different industries varies substantially (Jefferson et al., 2006). Innovation may play a more important role in economic performance for firms in an information-intensive industry (such as electronics and computer manufacturing) than for those in a less information-intensive industry (such as apparel and furniture manufacturing) (Porter and Miller, 1985). Thus, Industry is included in the research model. We hypothesize,

Hypothesis 4*: Industry will be associated with an exporting manufacturer's productivity.*

Research Method (Variables, Measurements and Dependent Variable)

A variety of economic metrics can be used to measure business performance. Jefferson et al., (2006) have examined the impact of R&D on two economic performance measures: productivity and profitability. But they have admitted that the two measures heavily overlap; in a perfect competitive market, productivity may correspond perfectly with profitability.

Productivity refers to the amount of output per input (capital, labor, or intermediate input) within a given period of time. Labor productivity (or sales per employee) is used in this study for three reasons: 1) labor productivity information is readily available in our data set; 2) labor productivity or sales per employee has been employed to measure business performance in previous studies (e.g., Janz, Lööf, and Peters, 2004); and 3) labor productivity not only points directly to profitability, but also reflects the efficiency of the firm's employees and competitiveness of the firm as a whole.

Independent variables

Innovation Intensity: Because of difficulties in measuring innovation output, researchers commonly use innovation input as a proxy for innovation intensity (Kohn and Scott, 1982). A variety of input-oriented variables are used as measures of innovation intensity, which include R&D expenditure, percentage of R&D investment in sales volume, percentage of process development investment in sales volume, and percentage of R&D personnel in a firm's workforce, along with output-based variables such as number of commercialized new product and number of patents (Kaplinsky & Paulino, 2005).

In this study, we use the percentage of R&D personnel in the workforce to measure innovation intensity of a firm. The percentage of R&D in the workforce not only represents the human talents that the organization dedicates to innovation, but also indirectly reflects the firm's expenditure on R&D. Furthermore, unlike R&D spending, which changes quickly from year to year, the percentage of R&D personnel in the workforce is a relatively constant and stable measurement.

Export Intensity: The variable is measured by the percentage of sales from exports. The percentage of export reflects an EM's export performance, and is also a good indicator of the firm's global competitiveness. Some prior studies (e.g., Bagchi-Sen, 2001) have used the percentage of sales from exports to measure export intensity.

Firm Size: Number of employees is frequently used as a measure for firm size, but it is not necessarily the best measure for firm size. Dickson, Weaverb, and Hoy (2006) imply that number of employees is often used to measure firm size because other firm size information such as sales and earnings is harder to obtain. We have firms' annual sales information in our dataset. Based on that information, we categorize the firms in the sample into three firm size groups: 1) large firm: more than $50 million annual sales, 2) medium firms: $10-50 million annual sales, and 3) small firm: less than $10 million annual sales.

Industry: Five industries with different innovation intensities (Cozzarin, 2006) are studied: apparel and furniture (low-innovation); chemicals and plastics (medium-innovation), and electronics (high-innovation). This categorical variable is coded in the general linear model (discussed in a later section) as follows: 1=Chemicals; 2=Electronics; 3 = Furniture; 4= Plastics; Omitted Category= Apparel.

Data Collection

The sample is drawn from firms advertised on alibaba.com, a reputed Chinese sourcing website whose major business is helping suppliers to market their products and buyers to find suppliers. The data are all self-reported to alibaba.com by suppliers, which are arguably reliable because, in order to gain credibility among the global buying community, the suppliers must provide data about their businesses in an honest manner. Furthermore, the majority of such data are certified by a third-party credit agency. If a supplier has failed to provide an essential piece of data to alibaba.com, we have gathered the information from other sources, such as the supplier's website.

To ensure the generalizability of the findings across different manufacturing sectors, we use a stratified sampling technique and sample firms from five industries (strata): two low-innovation industries (apparel and furniture), two medium-innovation industries (plastics and petrochemical), and one high-innovation industry (electronics) based on Cozzarin's categorization (2006). We first use keywords such as "apparel" and "clothing" to generate pools of firms that belong to different industries, and then randomly select firms from each of the industry pools.

In order to draw a sample of firms that are within the scope and focus of the present research, some firms are filtered out during the sampling process. First, because this study focuses on China, only firms in Mainland China are sampled. Secondly, only manufacturers are included in the sample; all non-manufacturing firms, such as trading companies, are excluded. Finally, because one of the objectives of the study is to examine whether export intensity has any effect on productivity, only firms that report an export percentage are included in the sample. Firms that do not provide complete information for the variables in the model are also dropped. In the initial sampling process, 372 firms are selected; 270 of those firms have met all above described criteria and are retained as the final sample for this study.

The data collected from the Company Profile database include annual sales, number of employees, number of R&D staff, percentage of R&D employees, export percentage, industry, and firm size (classified in terms of annual sales).

In this database, values for number of employees, annual sales, and number of R&D staff are given in ranges rather than in exact numbers. We use the average of the range to approximate the values. For example, if a company claims to have 10 to 20 R&D staff, we use 15: (10+20)/2. The average differs from the true value; however, since it is calculated systematically, the average is not biased in any direction, and thus, does not affect the validity of the study.

Sample

The final sample consists of 270 firms, which include 50 (18.5%) apparel manufacturers, 63 (23.3%) furniture manufacturers, 61 (22.6%) chemicals manufacturers, 41 (15.2%) plastics manufacturers, and 55 (20.4%) electronics manufacturers (Table 1). The sample has a good representation of firms of different sizes in terms of annual sales. Thirty-four firms are classified as large firms, having annual sales of US $50 million or more. Sixty-seven firms are classified as medium-sized firms with annual revenue between US $10 million and $50 million. The remaining 169 firms are classified as small firms with annual revenue of less than US $10 million.

The diverse industry and size distribution of the firms in our sample enhances the sample's ability to represent the manufacturing industry and thus improves the generalizability of our findings to firms of different size and sectors within the industry.

Table 1: Size and Industry Distribution of the Sample

		N	%
Firm Size	Small	169	62.6%
	Medium	67	24.8%
	Large	34	12.6%
Industry	Apparel	50	18.5%
	Chemicals	61	22.6%
	Electronics	56	20.7%
	Furniture	62	23.0%
	Plastics	41	15.2%
	Total	270	

Table 2 reports the profile of firms in the sample. On average, the firms were founded approximately eight years ago. The average number of employees is about 438, of whom about 7% are dedicated to R&D. The average annual sales are approximately $21 million, and the annual sales per employee are around $64,000. The firms, on average, have nearly 112,000 square feet of manufacturing space. The firms in the sample are quite export-intensive; on average 73% of sales are from exporting.

Table 2: Basic Information of Sampled Firms

	Mean	Std. Deviation
Sales	21013888.8889	27344942.06554
Sales per Employee (1000)	64.4241	123.86740
Firm Age	7.7778	7.92687
N of Employees	438.5185	315.59472
N of R&D Employees	24.7870	25.80986
Percentage of R&D Employees	7.2919	7.36109
Factory Size (square feet)	112059.7111	1104875.74237
Percentage of Revenue from Export	73.5370	25.12757

Statistical Method

We use general linear model (GLM) to explore the linear relationship between the dependent variable and independent variables. The GLM is essentially an extension of linear multiple regression for a single dependent variable. It is a commonly used technique to quantify the relationship between several independent or predictor variables and a dependent or criterion variable (StatSoft, 2008).

Results

Table 3 shows the descriptive statistics of Productivity, R&D, and Export. The table indicates that firm size is substantially associated with labor productivity. The means of Productivity in larger firms are consistently higher than those of smaller firms across all five industries. This validates the economy of scale theory. Industry's role in Productivity is less consistent across different firm size groups. Among small and medium-sized firms, apparel manufacturers achieve higher labor productivity than other industries. But among large firms, plastics manufacturers have the highest labor productivity.

On average, the firms dedicate approximately 7.29% of their employees to R&D. The Electronic manufacturers claim the highest R&D intensity (9.6%) while Plastics (5.4%) and Chemicals (5.8%) have the lowest percentage of their workforce working in R&D. In the Electronics industry, R&D intensity appears to be negatively associated with firm size, but in all other industries, R&D intensity seems to be positively associated with firm size.

The export intensity of the firms seems to be quite high. On average, the firms report 73.5% of annual sales from exports. This makes the sample a unique one for studying exporting manufacturers. Chemical manufacturers appear to have the highest export intensity, reporting an average of 85.5%. Across all industries, small firms have the highest export intensity. But within medium-sized firms and large firms, the relationship between firm size and export intensity is not so obvious. In Electronics and Apparel industries, the export intensity is higher in medium-sized firms than in large firms; however, in Furniture and Plastics industries, larger firms claim higher export intensity than medium-sized enterprises.

Table 3: Descriptive Statistics

Industry	FirmSize	Productivity	R&D	Export	N
Chemicals	Small	13.7500 (8.79119)	5.5938(5.38066)	86.3125(20.48199)	32
	Medium	45.0000(26.11165)	4.8194(3.31011)	84.1667(16.07275)	12
	Large	227.7778(105.76004)	9.5556(9.74489)	84.1667(10.68488)	6
	Total	46.9333(77.89726)	5.8833(5.69643)	85.5400(18.33388)	50
Electronics	Small	23.1879(22.77294)	10.6201(12.30548)	79.7059(20.53752)	34
	Medium	79.0234(30.47613)	8.5825(8.52668)	64.1176(24.95216)	17
	Large	220.0000(281.06939)	8.2667(5.90430)	54.0000(36.65151)	10
	Total	71.0129(131.89661)	9.6664(10.44392)	71.1475(26.53352)	61
Furniture	Small	15.2172(14.12085)	7.2626(7.53280)	77.9697(21.07499)	33
	Medium	93.4646(85.78734)	7.7012(4.83735)	66.2353(22.88430)	17
	Large	285.5556(362.83860)	9.8056(4.85159)	70.0000(24.49490)	6
	Total	67.9357(145.81035)	7.6682(6.52370)	73.5536(22.24730)	56
Plastics	Small	22.1667(20.35284)	4.4042(3.23441)	75.8250(21.92749)	40
	Medium	62.142(34.23416)	6.7679(6.33352)	56.7857(34.84069)	14
	Large	323.9583(289.27377)	8.1042(11.52394)	63.7500(20.65879)	8
	Total	70.1344(141.73915)	5.4153(5.70220)	69.9677(26.12515)	62
Apparel	Small	23.4444(24.71168)	7.4889(5.50686)	74.0333(25.76751)	30
	Medium	115.7143(129.33898)	6.2143(2.80330(	55.0000(28.13657)	7
	Large	262.5000(94.64847)	12.9167(11.33456)	43.7500(36.37192)	4
	Total	62.5203(96.24684)	7.8008(5.99424)	67.8293(28.54812)	41
Total	Small	19.6483(19.30773)	6.9857(7.63198)	78.6923(22.09746)	169
	Medium	76.8999(65.85872)	7.0583(5.95393)	65.7612(26.90223)	67
	Large	262.4020(252.05325)	9.2745(8.34415)	63.2353(29.07364)	34
	Total	64.4241(123.86740)	7.2919(7.36109)	73.5370(25.12757)	270

Outside parentheses are means; in parentheses are standard deviations.
Productivity: Measured by revenue per employee
R&D: Measured by percentage of R&D Employment
Export: Measured by percentage of Sales from Exporting

Initial GLM: Productivity (R&D, Export, FirmSize, Industry)

An important assumption of general linear modeling is normality. The significance levels and estimates of regression coefficients and confidence intervals calculated by the GLM procedure are valid only under the assumption of normality (SAS Institute, 1999). An analysis of the plots of the variables reveals Export distribution is approximately normal but two other variables--Productivity and R&D--are not normally distributed. So we conducted a log transformation and the resulting variables are approximately normally distributed.

We regressed lnProductivity (natural log of sales per employee) on lnR&D (percentage of employees working in R&D in log term), Export (percentage of sales from exports), FirmSize and Industry. The following is the General Linear Model:

$$lnProductivity=\beta_0 + \beta_1 FirmSize + \beta_2 Industry + \beta_3 lnR\&D + \beta_4 Export + e$$

The regression results reveal an R-Square of .694 and Adjusted R-Square of .684, indicating that about 68.4% of variance in sales per employee is accounted for by R&D, Export and the two categorical variables, Industry and FirmSize (Table 4).

Table 4: GLM Results (Dependent Variable: ln Productivity)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	296.873(a)	8	37.109	73.916	.000
Intercept	327.649	1	327.649	652.628	.000
FirmSize	229.428	2	114.714	228.493	.000
Industry	8.081	4	2.020	4.024	.003
LnR&D	36.076	1	36.076	71.859	.000
Export	1.128	1	1.128	2.247	.135
Error	131.034	261	.502		
Total	3406.217	270			
Corrected Total	427.907	269			

R Squared = .694 (Adjusted R Squared = .684)

The parameter estimates (Table 5) suggest that lnR&D, FirmSize, and Industry are significantly associated with lnProductivity (sales per employee), all with a p-value less than 0.001. The p-value for Export is 0.135, so no evidence is found for the relationship between Export and lnProductivity.

Table 5: Parameter Estimates (Dependent Variable: lnProductivity)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval	
					Lower Bound	Higher Bound
Intercept	6.459	.233	27.778	.000	6.001	6.917
FirmSize=1	-2.601	.137	-18.986	.000	-2.871	-2.331
FirmSize=2	-1.072	.150	-7.165	.000	-1.367	-.778
Industry=1	-.229	.155	-1.483	.139	-.534	.075
Industry=2	-.162	.144	-1.123	.262	-.446	.122
Industry=3	-.311	.147	-2.115	.035	-.601	-.021
Industry=4	.168	.145	1.161	.247	-.117	.454
lnR&D	.450	.053	8.477	.000	.345	.554
Export	.003	.002	1.499	.135	-.001	.006

FirmSize: 1= Small; 2= Medium; Omitted Category= Large
Industry: 1=Chemicals; 2=Electronics; 3 = Furniture; 4= Plastics; Omitted Category= Apparel
Computed using alpha = .05

Revised GLM: Productivity (R&D, FirmSize, Industry)

We then revised the General Linear Model by dropping *Export*. The resulting model is:

$$LnProductivity=\beta_0 + \beta_1 FirmSize + \beta_2 Industry + \beta_3 lnR\&D + e$$

Table 6 shows the regression results of the revised GLM model. The model yields an R-Square of .691 and an Adjusted R-square of .683. These are nearly identical to the R-Square and Adjusted R-square in the initial GLM model, indicating that *Export,* which is dropped from the model, truly contributes little to the general linear model.

Table 7 reports the parameter estimates for the revised model. As hypothesized, innovation intensity is found to be positively associated with labor productivity (t=4.87, p<0.000). This finding validates the increasingly controversial innovation-productivity link.

Table 6: GLM Results (Revised Model, Dependent Variable: lnProductivity)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	295.745(a)	7	42.249	83.755	.000
Intercept	525.222	1	525.222	1041.205	.000
FirmSize	237.850	2	118.925	235.759	.000
Industry	7.362	4	1.841	3.649	.007
LnR&D	35.307	1	35.307	69.992	.000
Error	132.162	262	.504		
Total	3406.217	270			
Corrected Total	427.907	269			

R Squared = .691 (Adjusted R Squared = .683)

Hypothesis 4 states that industry will be associated with labor productivity. That hypothesis is supported with a p-value of 0.008. Based on the parameter estimates, furniture manufacturers (industry =3) seem to be significantly less productive than apparel manufacturers (omitted industry in the model) in terms of sales per employee. But the regression coefficient estimates for industries 1 (Chemicals), 2 (Electronics), and 4 (Plastics) are not significant; so no evidence is found that there is a difference in productivity between those industries and apparel manufacturers.

Table 7: Parameter Estimates (Revised Model, Dependent Variable: lnProductivity)

Parameter	B	Std. Error	t	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Higher Bound
Intercept	6.598	.214	30.880	.000	6.178	7.019
FirmSize=1	-2.559	.134	-19.037	.000	-2.824	-2.294
FirmSize=2	-1.067	.150	-7.115	.000	-1.363	-.772
Industry=1	-.179	.151	-1.183	.238	-.477	.119
Industry=2	-.146	.144	-1.012	.313	-.430	.138
Industry=3	-.290	.147	-1.979	.049	-.579	-.001
Industry=4	.175	.145	1.204	.230	-.111	.461
LnR&D	.443	.053	8.366	.000	.339	.548

Computed using alpha = .05. FirmSize: 1= Small; 2= Medium; Omitted Category= Large Industry: 1=Chemicals; 2=Electronics; 3 = Furniture; 4= Plastics; Omitted Category= Apparel

FirmSize and R&D Productivity

Hypothesis 3 posits that firm size is positively associated with productivity (sales per employee). The hypothesis is supported with a p-value of 0.000 (Table 7). The study reveals that the larger the firm, the higher labor productivity it achieves. However, a much higher marginal productivity for R&D intensity is found in the largest firms than in medium-sized firms, which is consistent with findings by Jefferson et al., (2006).

In order to further examine the role that firm size plays in the effect of R&D intensity on productivity, we generate separate general linear models for different firm size groups. Table 8 reports the results. The comparison of the estimates of regression coefficients demonstrates that the effect of R&D intensity on labor productivity declines with firm size. This finding is consistent with decreasing returns to firm scale in R&D revealed by Graves and Langowitz (1993). Therefore, no evidence is found in this study for the Schumpeterian Hypothesis.

Conclusion

The study demonstrates that R&D intensity plays a significant and positive role in an EM's productivity. Firm size is also found to be positively associated with productivity. But the effect of R&D intensity on productivity seems to decline as firm size increases. The finding is consistent with a large body of literature, which argues that, compared with larger firms, smaller firms tend to be more productive and efficient innovators (Kitching J. and Blackburn, 1998). Smaller firms are more willing to take risks in innovative activities than larger companies (Hall, 1995). They are more flexible and adaptive to external threats and opportunities, and thus, achieve higher innovation productivity (Rothwell and Dodgson, 2007).

Table 8: Effect of R&D on Productivity (Comparison Based on Firm Size)

	Small Size				Medium Size				Large Size			
Parameter	B	Std. Error	t	Sig.	B	Std. Error	t	Sig.	B	Std. Error	t	Sig.
Intercept	4.299	.246	17.475	.000	5.251	.346	15.168	.000	6.175	.469	13.155	.000
lnPercRD	.545	.073	7.507	.000	.305	.093	3.296	.002	.271	.123	2.194	.037
Industry=1	-.061	.190	-.322	.748	-.562	.279	-2.016	.048	-.094	.464	-.202	.841
Industry=2	-.145	.186	-.783	.435	-.132	.261	-.504	.616	-.371	.427	-.869	.392
Industry=3	-.364	.187	-1.946	.053	-.136	.261	-.519	.606	-.356	.462	-.770	.447
Industry=4	.347	.182	1.905	.058	-.316	.270	-1.169	.247	.173	.446	.388	.701

Further, we find no evidence that an EM's export intensity has any effect on its productivity. The finding is in line with some prior studies. For example, Kunst and Marin (1989) have examined the relationship between exports and productivity and have found no causal linkage from exports to productivity. The relationship between export and business productivity, therefore, remains controversial (Mahadevan, 2007). The findings of this study have important implications for businesses. With the increasing use of external technological development through outsourcing and strategic alliances, exporting manufacturers may overlook the need for in-house R&D. This study provides timely empirical evidence that in-house R&D still matters for their business productivity. Also, the study finds that the payoff (in terms of productivity) from R&D for smaller firms seems to be higher than larger firms. Regulatory agencies and relevant business associations may use this finding as a foundation and formulate strategies that stimulate R&D investment among small and medium-sized enterprises (SMEs).

We highlight a couple of limitations in this study. First, like many other empirical studies on R&D, which usually omit a variety of issues related to R&D and focus instead only on effects of specific key inputs of R&D on business performance (Black and Lynch, 2001; Hitt and Brynjolfsson, 2002), the present study is limited by its scope as well because of data availability. The study examines only the effect of one dimension of R&D—R&D intensity—on business productivity. Other dimensions of R&D, such as the quality of R&D and innovation behavior fit, which may also have an effect on productivity (Fichman, 2004), are not included in the study. Future research should incorporate those dimensions.

Secondly, the sample in this study was drawn from alibaba.com, which may over-represent SMEs and under-represent large companies because a relatively higher proportion of businesses that use alibaba.com are SMEs. In addition, our sample includes firms from only five industries; the extent to which the findings can be generalized to other industries is unknown.

The present study can be extended in future studies in the following ways: First, a similar study can be conducted with a more representative sample that includes EMs from multiple countries. Country-to-country comparisons can be made to determine the extent to which R&D, firm size, and export may have on productivity. Secondly, this study only examines the linear association between R&D intensity, export, firm size and productivity. The findings have no implications for causal linkages between those variables. Future studies can use the findings of this study as a foundation and examine the causal relationship among those variables.

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