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Abstract

The objective of this paper is to empirically examine the relationship between innovation, productivity and trade intensity using firm-level data from the Malaysian manufacturing sector. Evidence from this paper suggest that exporters do have higher productivity levels compared to non-exporters. Regressions on production functions indicate that exporting may not necessarily be an important driver of productivity growth compared to capital and labour. Estimates from structural models show that the mechanisms by which exporting may influence productivity in Malaysia is one in which productivity gains are driven primarily by process innovation (rather than product innovation) which, in turn, is influenced by exporting through the decision to undertake R&D.

JEL Classification: F14, L11, L60

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1 Introduction

Growth theories that have been proposed since the time of Adam Smith has consistently featured innovation, productivity and trade as key contributors of economic growth. In the *Wealth of Nations*, for example, Adam Smith argues that growth is driven by productivity gains from division of labour and specialization, the extent to which is limited by the size of market. Smith further argues that exports, which expands market size, is therefore a avenue for the growth of small economies.[2] In the modern growth theories, technological innovation occupies a central role. In Solow (1956)'s seminal paper, exogenous technological innovation augments labour productivity to ensure long-term economic growth. Since the 1980s, attempts have been made to model technological innovations endogenously by either incorporating spillovers from investment in physical and human capital (Romer (1986)) or differences in the variety and quality of inputs (Romer (1990)). Endogenous growth theories have also been extended to relate trade or openness to growth by arguing that the source of productivity growth can come from other countries. The mechanism by which this occurs is the absorbing or imitating innovations from other countries made possible by trade or openness.

Despite the enormous amount of research undertaken on growth theories, there remain some disquiet over the robustness of these findings. This can be attributed to the restrictive assumptions and quality of data used is such

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[2]This theory is also known as the vent for surplus theory.

studies (Romer (1994), p.20 and Pack (1994)). As a result, some have advocated more empirical work at the micro-level linking innovation, productivity and trade (e.g. (Edwards (1998)), p.396.). In recent years, scholars have been able to address this research challenge due to greater availability of firm or plant-level data. The literature that has emerged essentially seeks to empirically verify, using firm or plant-level data, the relationships between innovation, productivity and trade. However, most of such empirical studies focus primarily on analyzing the relationships between two of these three factors but not all three simultaneously. For example, much of the firm-level empirical literature have sought to understand the relationship between productivity and exports. In this literature, productivity improvements are not explicitly modeled as a consequence of technological innovations. There is thus a need to empirically examine the relationship between productivity, exports and trade within a single framework.

The objective of this paper is to empirically examine the relationship between innovation, productivity and trade using firm-level data from the Malaysian manufacturing sector. The outline for the rest of the paper is as follows. Section 2 discusses the related literature. This is followed by a discussion of the data and methodology used in this study in Section 3. Results from the econometric analysis are discussed in Section 4. Section 5 concludes.

2 Related Literature

The literature linking innovation, productivity and trade is enormous. Instead of listing all the contributions in this area, we confine our discussion to main findings from selected firm-level studies with particular emphasis on survey articles. Overall, three distinct but inter-related strands of literature can be discerned in this area. The first strand comes from the literature on the economics of innovation which attempts to relate innovation to productivity. The second strand comes primarily international trade which focuses on the relationship between productivity and exports. A subset of this strand of literature constitutes the third strand, which incorporates all three elements, namely innovation, productivity and exports, in their analysis. In what follows, we review the key findings from these three strands of related literature.

2.1 Innovation and Productivity

One of the earliest contribution that examined the relationship between research, innovation and productivity using firm-level data is Crepon *et al.* (1998). Using data from the French manufacturing sector, the paper examined both (i) the impact of research on innovation and, (ii) the impact of innovation and research on productivity. The paper found that the probability of a firm undertaking research increases with its size, market share, diversification and with demand pull and technology indicators. Research intensity (measured by R&D expenditure) for a firm undertaking research increases with the same variables except for size. Innovation output, measured by patent numbers or innovative sales, increases with research intensity and with demand pull and technology indicators. Higher productivity is associated with higher innovation output.

Griffith *et al.* (2006) extends the work of Crepon *et al.* (1998) by using a larger set of data covering four European countries, namely, France, Germany, Spain and the United Kingdom. In their study, the authors found that firms' decisions to undertake research is influenced by size, availability of national funding, whether they operate in international markets and when there is greater use of methods to protect innovation. Unlike Crepon *et al.* (1998), the authors make a distinction between product and process innovations. The authors found that greater research effort makes firms more likely to become innovators. However, firms with higher investment per employee are more likely to be process innovators. In terms of protection of innovation, this is more important for process than product innovation. The sources of innovation differ for each type of innovation: suppliers are more important for process innovation and buyers are more important for product innovation. Finally, there were significant variations in the relationship between innovation and productivity in the paper.

2.2 Productivity and Exports

Greenaway and Kneller (2004) provides a review of the microeconomic (theoretical) and microeconometric (empirical) literature on the benefits of exporting. Theoretically, there are many ways by which productivity at the firm level is associated with exports. In the presence of fixed (sunk) cost of entering exports markets, the more productive firms could self-select to enter such markets i.e. learning to export. Firms could also learn by exporting. This could be due to greater incentives for learning in export markets due to higher rates of return and / or greater competitive pressures in such markets. The empirical literature reviewed by the authors suggest that there is some evidence supporting the self-selection theory. However, the evidence on learning by exporting is fairly inconclusive. The authors cite a few theoretical conjectures that could explain these results. These conjectures include the importance of country size and distance from the technology frontier. The positive impact of entry into export markets on productivity is greater in countries with smaller domestic markets and for firms that are further away from the technology frontier.

Wagner (2007) provides a more recent review of the firm-level evidence on the relationship between exports and productivity. The author discusses some of newer developments in empirical methods that have been used to investigate this topic. These include the use of matching approach to examine the impact of starting or stopping to export on productivity, the use of the Kolgomorov-Smirnov test to for the stochastic dominance of the productivity distributions for exporters over non-exporters and quantile regressions to examine the variations in the effect of exporting on productivity across the conditional productivity distribution. Overall, his verdict is more or less similar to that of Greenaway and Kneller (2004), namely, exporters are more productive than non-exporters, the more productive firms self select into export markets but exporting does not necessarily improve productivity.

The review by Greenaway and Kneller (2007) provides a theoretical and empirical survey on firm heterogeneity, exporting and productivity. Their paper provided a summary of the larger body of literature that goes beyond the debate on the direction of causality between productivity and export. The decision to participate in exporting is discussed in terms on the role of exchange rates (impact of devaluation/appreciation), policy innovation (trade liberalization, grants) and agglomeration effects (spillovers from other exporters, region or industry). In their paper, they reaffirm the importance of self-selection compared to learning. Of particular interest is their discussions on research that models the endogenous decision to start exporting. In such models, firms undertake investment in new technologies to achieve pre-entry (into export markets) productivity gains. Two papers of such nature, namely Baldwin and Gu (2004) and Aw *et al.* (2007), are discussed in greater detail in the next sub-section. Another important topic discussed in Greenaway and Kneller (2007) is that of exporting and foreign direct investment (FDI). In reviewing the literature on this topic, the authors find strong empirical evidence that multinationals have higher productivity compared to exporters. The degree of firm size distribution also has influence over the relative levels of exports to FDI.

2.3 Innovation, Productivity and Exports

In general, there has been relatively less emphasis on modeling of the innovation process in the literature on exports and productivity. In the classic paper by Melitz (2003), the process of innovation takes the form of a random productivity draw from an exogenous distribution (see **Figure 1**). In this model, firms with productivity levels exceeding an endogenously determined productivity threshold will export their products.

One of the earliest paper to include a more explicit treatment of innovation within models linking productivity to exports is that by Baldwin and Gu (2004). In their paper, the authors provide evidence that export market participation by Canadian firms was driven by trade liberalization. These exporting firms were also found to be more innovative via greater use of advanced technology and staff training.

Another paper in international trade that examines the role of innovation in productivity and exports is Aw *et al.* (2007). The paper is methodologically different from that by Baldwin and Gu (2004) in that firms' exit decisions and productivity evolution are modeled endogenously and estimated using the Heckman's sample selection model. One of their key finding is that Taiwanese firms that engage in R&D and/or workers' training and export participation experience larger productivity increases than firms that only exports.

The paper by Almeida and Fernandes (2006) provides evidence that both importers and exporters are more likely to adopt a new technology compared to other firms. Using firm-level data from 43 developing countries, the authors also found evidence that majority foreign-owned firms are less likely to undertake technological innovations compared to domestic firms. However, no attempts were made to model productivity explicitly in their work.

3 Model and Specification

The methodologies adopted in research on innovation, productivity and exports are fairly diverse. This is probably due to the different research questions address in some of these studies as well as the constraints imposed by data limitations. An eclectic approach is therefore adopted for this study to provide opportunities for comparison with existing results in this literature. We adopt three approaches for this study, namely stochastic dominance, quantile regression and the innovation-productivity-exports model.

3.1 Stochastic Dominance

Productivity differentials between exporters and non-exporters can be tested via stochastic dominance of the productivity distribution for exporters over the productivity distribution for non-exporters. Let F and G be the cumulative distribution functions of productivity (z) for exporters and non-exporters. The first-order stochastic dominance of F relative to G implies that:

$$F(z) - G(z) \geq 0 \tag{1}$$

for all values of z, with strict inequality for some z.

We test this condition using the Kolgomorov-Smirnov test for both definitions of exports. Productivity is measured in terms of value-added per worker.

3.2 Quantile Regression

The quantile regression approach can be used to investigate whether the productivity effects of exporting differs across the conditional productivity distribution. We adopt a version of the specification used in (Yasar *et al.* (2006)). We also compare between the OLS with quantile regression estimates. A Cobb-Douglas specification is used for the regression:

$$\ln \mathrm{Output}_i = \beta_0 + \beta_1 \ln \mathrm{Capital}_i + \beta_2 \mathrm{Labour}_i + + \beta_3 \mathrm{Export}_i + \beta_4 \mathrm{Ownership}_i + e_i \tag{2}$$

where i is the index for the firm, Output is proxied by value-added, Capital is proxied by fixed asset, Labour is total number of workers, Export is a dummy variable for exports (taking the value of one when a firm exports, zero otherwise) and Ownership is a dummy for local ownership (taking the value of one when 50 percent or more of a firm's equity is owned by Malaysians, zero otherwise).

3.3 Innovation-Productivity-Exports Model

For an empirical analysis of innovation, productivity and exports, we can use a version of the structural models used in Crepon *et al.* (1998) and Griffith *et al.* (2006). There are two components in the model (see **Figure 2**). First, research investment influences innovation output. Second, innovation output influences productivity. Such a model has the merit of reducing simultaneity and endogeneity problems. The standard specification comprises four equations. The first two sets of equations pertain to research activities.

First, firms have to decide whether to engage in R&D or not. The propensity of firm i to undertake innovation-related activities such as R&D is modeled as:

$$rd_i^* = x_{0i}\beta_0 + e_{0i} \tag{3}$$

where rd_i is the observed binary endogenous R&D variable, x_{0i} are the explanatory variables, β_0 the coefficient vector and e_{0i} the error term. The explanatory variables x_{0i} include the degree of local ownership, market concentration (measured by the Herfindahl-Hirschman Index, HHI), exporting activity, technological characteristic of industry (whether how or high-medium technology), and firm size (in terms of total number of employees).[3].

The R&D intensity of firm i is modeled as:

$$r_i^* = x_{1i}\beta_1 + e_{1i} \tag{4}$$

where x_{1i} are the explanatory variables, β_1 the coefficient vector and e_{1i} the error term. Following Crepon *et al.* (1998), we assume $x_{0i} = x_{1i}$ i.e. the set of explanatory variables for the propensity to undertake R&D is the same as R&D intensity.

Both equations (1) and (2) are jointly estimated as a generalized Tobit model by maximum likelihood.

Next, we model the innovation production function as:

$$g_i^* = \beta_2 r_i^* + x_{2i}\beta_3 + e_{2i} \tag{5}$$

where g_i^* is the binary innovation indicator (i.e. taking the value of 0 or 1), r_i^* the latent innovation effort and x_{2i} represents the other explanatory

[3]Note that since we are using cross-section data, we are unable to distinguish between "exporting for learning" and "learning from exporting"

variables which include size of firm (proxied by total employment), export activity and local ownership. The estimation of equation (3) is carried out by carrying out probit estimations using the predicted value of R&D intensity (r_i^*). Following Griffith *et al.* (2006), separate estimates are carried out for product and process innovations.

The final component of the model involves the use of an augmented Cobb-Douglas production function to measure productivity:

$$q_i = \alpha_1 k_i + \alpha_2 s_i + \alpha_3 g_i^* + \alpha_4 w_i + e_i \tag{6}$$

where q_i is labour productivity (natural log of value-added per worker), k_i the investment intensity proxied by fixed asset per worker, s_i percentage of employees with college/university degrees, g_i^* is the predicted innovation input and w_i the firm size.

3.4 Data

The cross-section data for this study comes from the *National Survey of Innovation* conducted by the Malaysian Science and Technology Information Centre (MASTIC), Ministry of Science, Technology and Innovation. The reference period for the survey is 2002-2004. Data pertaining to turnover, employment and export share of sales are for year 2004. In the survey questionnaire, firms are asked whether they innovate or not based on definitions of innovation that are used in the *Oslo Manual*. Innovation can involve product or/and process innovation. The reference period for response to this question is 2002-2004.

The total number of observations in our sample data is 485 firms of which 261 carry out some form of innovation while 224 firms do not innovate at all. Of the 261 innovating firms, 190 firms carry out both product and process innovation while 27 firms and 44 firms carry out only product innovation and process innovation, respectively. Of the 485 firms, 341 firms (70.3% of total) export their products. Of these 341 firms, 210 firms obtain equal to or more than 50 percent of their revenues from exports. A total of 376 firms (77.5%) have majority local ownership (i.e. having local equity $\geq$ 50%). **Table 1** provides additional summary statistics of the data used for this study.

Data on industry market concentration comes from a separate source, namely the Department of Statistics. The estimates of the Herfindahl-Hirschman

Index (HHI) are for year 2000. The scale adopted for the HHI is from zero to one, where a unit value is obtained in the monopoly case. Estimates of the HHI at the aggregated level (2-digit) are derived from disaggregated 5-digit HHI estimates (computed by the Department of Statistics) using a weighted approach. The weights used are based on turnover figures for the various industries obtained from the Department of Statistics' *Census of Manufacturing Industries 2001.*

The variable representing technological characteristic of industry (whether how or high-medium technology) comes from Hatzichronoglou (1997) who provides a classification scheme for manufacturing industries that we can use for this purpose.

4 Empirical Results

In this section, we discuss the empirical results from the various models and specifications set out in the previous section.

4.1 Stochastic Dominance

The Kolgomorov-Smirnov test for differences in productivity is presented in (**Table 2**). The first row in the table tests the hypothesis that productivity (measured by value-added per worker) for non-exporters is lower than exporters. The approximate p-value obtained is 0.010 which is significant. The second row tests the hypothesis that productivity for non-exporters is larger than exporters. The p-value for this is 0.912 which means this hypothesis is rejected. Results from the combined test, which tests for productivity differences between non-exporters and exporters are reported in the third row. Both the approximate p-value (0.005) and the corrected p-value (0.004) indicates that there are statistically significant differences in productivity between non-exporters and exporters. These results appear to be consistent with those obtained for other studies involving countries such as United Kingdom, Germany and Spain.

4.2 Quantile Regression

The results from the OLS and quantile regressions are summarized in **Table 3**). In the OLS regression, both capital (proxied by fixed asset) and labour (proxied by total number of employees) variables are statistically significant. These variables are also statistically significant at all quantiles. The value of the estimated coefficients for capital indicates that the productivity gains from capital input declines as we move from a lower to higher quantiles. This implies that lower productivity of capital is associated with larger output (proxied by value-added). No such effects are observed for labour inputs. These results are slightly different from that obtained by Yasar *et al.* (2006) where the value of the coefficients for capital increases over larger quantiles and the value of the coefficients for labour generally decline over larger quantiles. Such differences suggest that the type of technologies adopted in both countries' manufacturing sector (Malaysia and Turkey) may be different.

4.3 Innovation, Productivity and Exports

The results from the research equation estimated using the Heckman selection method provide some insight on both the decision to undertake R&D and on the amount of expenditure on R&D. The firms' decision to undertake R&D is positively influenced by three variables (i.e. statistically significant), namely, export, firm size, and perception of industry's technology (**Table 4**). However, in terms of R&D expenditure, only firm size has a positive effect.

Estimates from the innovation equation (**Table 5**) provide us with an idea of the important determinants of the propensity to innovate for both product and process innovation. All the variables (R&D expenditure, firm size, exports and local ownership) are statistically significant and with the expected signs i.e. positively related to product and process innovation. Based on the values of the coefficients, these variables have a greater impact on process innovation compared to product innovation. Such findings are consistent with the view that developing countries are driven more by process innovation than product innovation.

In terms of sources of productivity, the four statistically significant variables include investment intensity, product innovation, process innovation and labour quality (**Table 6**). The positive values of the coefficients for investment intensity and labour quality indicate that higher investment intensity and labour quality are associated with higher levels of productivity.

Interestingly, the signs of the coefficients signs for the two innovation variables are different. This suggests that product innovation and process innovation impact productivity differently. Product innovation is negatively related to productivity while process innovation is positively related to productivity. These results seem to justify many of the assumptions on innovation in the productivity-trade literature, namely productivity is driven mainly by process innovations.

5 Conclusion

Innovation, productivity and exports have long be considered the cornerstones of economic growth. Earlier empirical studies have primarily attempted to examine the roles and contributions of these factors to growth using macroeconomic or industry-level data. The greater availability of plant or firm level data has generated a new branch of empirical literature focusing on microeconometric investigations of the the relationship between the three variables. This study has attempted to investigate the relationship between innovation, productivity and exports in the Malaysian manufacturing sector using data from the *National Survey of Innovation 2002-2004*. The methodology adopted for the empirical analysis is an eclectic one - due to the diversity of methodologies observed in the literature as well as due to data limitations.

The stochastic dominance test for productivity differentials suggests that exporters do have higher productivity compared to non-exporters. However, evidence from the OLS and quantile regressions on the production function indicates that exporting may not necessarily be an important driver of productivity growth amongst firms. In these regressions, capital and labour are significant variables - consistent with the contributions of these factors in the growth theory literature. Interestingly, capital has declining impact on larger output.

Results from the structural models provide further insights into the complex relationships between innovation, productivity and exports. Exporting and industry technological characteristics may influence the decision to undertake R&D but has no effect on R&D expenditure. Only firm size has impact on both the decision and expenditure on R&D. All the variables (R&D expenditure, firm size, exports and local ownership) are statistically significant determinants of the propensity to innovate, be it it product or process innovation. These variables have greater impact on process innovation compared to product innovation. Investment intensity, product innovation, process innovation and labour quality are all significant explanatory variables in the productivity equation. Interestingly, product innovation is negatively related to productivity while process innovation is positively related to productivity.

Is Malaysia's experience similar to those of other countries? The results obtained in this paper suggest a more complex answer. Exporters appears to be more productive than non-exporters, a finding consistent with the existing literature. The mechanism by which this occur in Malaysia is one in which productivity gains are driven primarily by process innovation (rather than product innovation) which, in turn, is influenced by exporting through the decision to undertake R&D.

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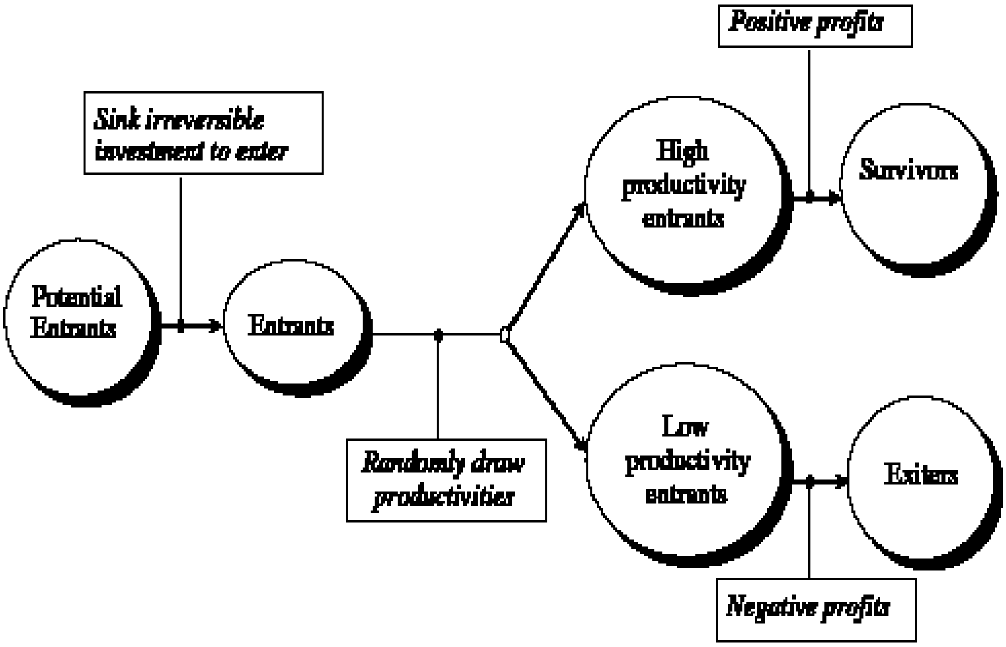

Figure 1: Inter-Firm Reallocation and Productivity Growth
Source: Greenaway and Kneller (2007)

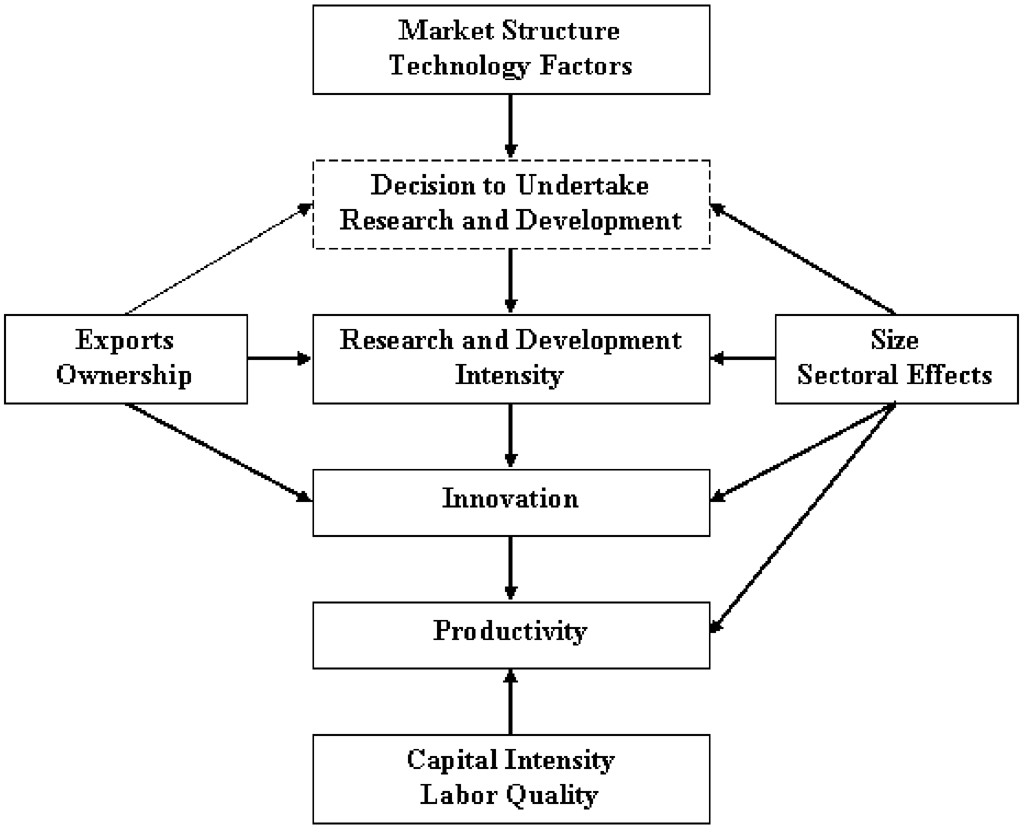

Figure 2: Research-Innovation-Productivity Model

Table 1: Descriptive Statistics

Variable	N	Mean	SD	p25	p50	p75
% Local Ownership	474	74.79	39.68	51	100	100
Total Employment	474	246.53	511.29	22	74.5	258
Fixed Asset (RM)	457	4.90e+07	3.74e+08	144,099	3,000,000	1.83e+07
% Turnover Exported	443	39.43	40.85	0	23	87
Total Turnover	471	6.40e+07	3.17e+08	1,328,399	9,374,206	4.00e+07
R&D Expenditure (RM)	115	4.57e+10	4.88e+11	0	1.80e+07	1.29e+08
No.Graduate Employees	465	19.90	75.0	0	3	10

Table 2: Stochastic Dominance Test for Productivity Differences between Non-Exporters and Exporters Using the Two-Sample Kolgomorov-Smirnov Test

Smaller Group	D	P-Value	Corrected
Exporters	0.1816	0.003	
Non-Exporters	-0.0227	0.912	
Combined K-S	0.1816	0.020	0.015

Table 3: Production Function: OLS and Quantile Regression

COEFFICIENT	(1) OLS ln(VA)	(2) q(0.10) ln(VA)	(3) q(0.25) ln(VA)	(4) q(0.50) ln(VA)	(5) q(0.75) ln(VA)	(6) q(0.90) ln(VA)
Capital	0.347***	0.437***	0.292***	0.283***	0.220***	0.240***
	(0.043)	(0.16)	(0.033)	(0.032)	(0.058)	(0.071)
Labour	0.611***	0.542**	0.711***	0.678***	0.737***	0.773***
	(0.070)	(0.26)	(0.056)	(0.051)	(0.080)	(0.093)
Export	-0.0303	-0.0635	-0.112	0.161	0.0488	-0.202
	(0.19)	(0.54)	(0.15)	(0.14)	(0.21)	(0.24)
Local Ownership	0.293	0.496	0.300**	0.100	0.0667	0.0445
	(0.19)	(0.53)	(0.15)	(0.13)	(0.20)	(0.22)
Constant	6.897***	4.499**	6.909***	7.644***	9.055***	9.315***
	(0.52)	(1.91)	(0.42)	(0.38)	(0.67)	(0.83)
Observations	320	320	320	320	320	320
R^2	0.64	.	.	.	.	.

Standard errors in parentheses
*** p¡0.01, ** p¡0.05, * p¡0.1

Table 4: Research Equation

Coefficient	(1) R&D Expenditure	(2) Select	(3) atanh ρ	(4) $\ln \sigma$
Local Ownership	-0.437	-0.204		
	(0.58)	(0.17)		
HHI	0.000310	0.0000113		
	(0.00031)	(0.000086)		
Export > 0%	-0.644	0.939***		
	(1.73)	(0.24)		
High-Medium Tech	0.338	0.638***		
	(1.09)	(0.19)		
Size	-0.00101**	0.000304**		
	(0.00049)	(0.00012)		
Constant	13.41***	-2.123***	-0.105	0.834***
	(4.03)	(0.32)	(0.66)	(0.093)
Observations	474	474	474	474

Standard errors in parentheses

*** p¡0.01, ** p¡0.05, * p¡0.1

Table 5: Innovation Equation

COEFFICIENT	(1) Product Innovation	(2) Process Innovation
R&D Expenditure	0.700***	1.119***
	(0.21)	(0.23)
Size	0.00116***	0.00171***
	(0.00026)	(0.00028)
Export $>$ 0%	1.361***	1.746***
	(0.19)	(0.20)
Local Ownership	0.303*	0.690***
	(0.18)	(0.19)
Constant	-10.63***	-16.64***
	(2.97)	(3.17)
Observations	474	474

Standard errors in parentheses
*** p¡0.01, ** p¡0.05, * p¡0.1

Table 6: Productivity Equation

COEFFICIENT	(1) Output	(2) Output
Investment Intensity	0.309***	0.321***
	(0.043)	(0.044)
Product Innovation	-2.053***	-2.186***
	(0.76)	(0.79)
Process Innovation	1.655***	1.650***
	(0.61)	(0.63)
Labor Quality	1.931***	1.981***
	(0.61)	(0.62)
No. of Employees	-0.000314*	
	(0.00018)	
1-49 Employees		0.224
		(0.25)
50-99 Employees		0
		(0)
100-249 Employees		0.309
		(0.27)
250-999 Employees		0.200
		(0.27)
$\geq$ 1000 Employees		0.478
		(0.45)
Constant	7.043***	5.827***
	(0.49)	(0.91)
Observations	315	315
R^2	0.22	0.22

Standard errors in parentheses

*** p¡0.01, ** p¡0.05, * p¡0.1