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## R&D, Value Chain Location and Firm Performance in the Global Electronics Industry

By

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## 1. Introduction

Value chains in the electronics industry have steadily disintegrated across corporate and national boundaries since the early 1990s. Outsourcing has become a strategic necessity, especially in fiercely competitive and rapidly changing sectors such as electronics. According to Baldwin and Clark (2006), the electronics industry has evolved to a modular structure in which firms keep a smaller set of activities in-house (a smaller footprint) by outsourcing the functions that do not constrain overall business performance. In the past, large electronics firms designed and developed their own products, often using their internal supply chains (Linden, Kraemer, and Dedrick 2007). Today lead firms (brand name manufacturers) focus on core competencies, especially product innovation, marketing, and other activities related to brand development, while using specialized suppliers for non-core functions such as manufacturing (Sturgeon 2002; Yeung 2006). By outsourcing, lead firms can get more products faster, reap value from innovations before imitators enter the market, and all of these without making huge capital investments or idling in-house capital assets to meet rapid technological change and volatile market demand (Sturgeon 2002).

Innovation is often a source of value creation and competitiveness (Schumpeter 1934). In today's electronics industry, innovation is carried out by various value chain participants, including lead firms, contract manufacturers (CMs), and component suppliers. These diverse companies often cross national borders and form global production networks (or value chains). These firms are independent organizations, working closely to leverage local knowledge into commercial success. Value created from innovation in the global electronics industry is distributed not only to the lead firm, but also to partners in the firm's supply chain (Dedrick, Kraemer, and Linden 2008). While most core technological innovations are done by component suppliers upstream in the industry, lead firms innovate by identifying new product markets and designing products that incorporate new technologies to serve those markets.

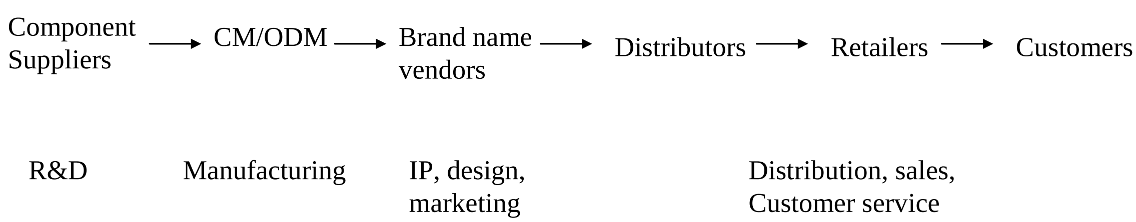
However, there is little understanding of who benefits most from innovation in the global electronics industry. The key questions we raise for this research are as follows: What is the relationship of R&D to firm performance?  Do firms at different levels in the value chain, particularly lead versus non-lead firms, perform differently? Do lead firms capture higher value from R&D than non-lead firms? In order to tackle these questions, we conduct an exploratory study by examining empirically the relationship of R&D spending and location in the value chain to firm performance in the global electronics industry. We employ the Electronic Business 300 data set and the Hoovers database for the six years from 2000 to 2005.

In the next section, we describe the global production network of the electronics industry. Section 3 discusses the relationship of R&D and value chain location to firm performance, and proposes hypotheses. Section 4 describes our general empirical model, as well as our data sources and research methodology. We outline our results in Section 5. Discussion and conclusions are provided in Section 6.

## 2. The Global Production Network of the Electronics Industry

Today's electronics industry consists of a global production network (supply chain) of independent component suppliers, CMs or original design manufacturers (ODMs), branded firms, distributors, and retailers. The supply chain model (Figure 1) shows various activities, such as R&D, manufacturing, design and branding, and distribution, sales and service, which are involved in creating value from component suppliers to final customers. Each producer purchases inputs and then adds value, which then becomes part of the cost of the next stage of production. The sum of the value added by everyone in the chain equals the final product price (Dedrick, Kraemer, and Linden 2007; Linden, Kraemer, and Dedrick 2007).

Figure 1. Generic Electronics Supply Chain




Source: Dedrick, Kraemer, and Linden (2007)

Most component-level R&D is done by large manufacturers who supply high-value components such as visual displays, hard drives or key integrated circuits. These components are the most likely to embody proprietary knowledge that helps differentiate the final product and command commensurately higher margins, thereby accounting for a relatively large share of the total value added along the supply chain. Most other components are low value, such as capacitors and resistors. The suppliers of these components contribute relatively little innovation and earn thin margins, thereby accounting for a small share of the total value added (Dedrick, Kraemer, and Linden 2007; Linden, Kraemer, and Dedrick 2007).

The assembly of these components into the final product is done mostly by a number of large CMs or ODMs who provide assembly services to brand name manufacturers. These assemblers compete fiercely for high-volume opportunities, limiting their margins.

Branded firms collaborate with CMs/ODMs to bring new products to market using components from upstream suppliers. These lead firms are system integrators, specializing in high return premium product markets and high value-added activities such as R&D, product design, branding, and marketing (Sturgeon 2002; Yeung 2006). While these firms innovate through product design and system integration, the upstream innovation is a major factor shaping the configuration of final products.

Creation of new product markets by lead firms in turn can influence the direction of upstream innovation in components (Dedrick and Kraemer 2007). Lead firms must thus work closely with component suppliers to integrate advanced technologies in highly sophisticated designs. They can create value by leveraging the innovations of upstream firms to enhance products that consumers find useful and usable (Dedrick, Kraemer, and Linden 2007; Linden, Kraemer, and Dedrick 2007).

Distribution is mostly decentralized and local, although there are a few large distributors who operate internationally, such as Ingram Micro and Arrow Electronics (Dedrick and Kraemer 2007). Sales are done by large retail chains such as Best Buy, Circuit City, Fry's, Cosco, Staples, and WalMart. Retail outlets operate on a relatively fixed margin from the vendor and seek scale and reach, but price competition plus capital and operating costs keep margins low. Sales are also done increasingly by branded vendors directly online, and in cases such as Apple and Sony, through their own stores. The use of direct sales can contribute to the lead firm's margins if retail operations are cost effective (Dedrick, Kraemer, and Linden 2008).

As described above, value created from innovation in the global production network is spread out to the lead firm, as well as other firms in the firm's supply chain, such as component suppliers and CMs/ODMs. Our main focus in this paper is on three types of firms in the global production network: lead firms, CMs/ODMs, and component suppliers.

## 3. Profiting from Innovation

### 3.1 R&D and value chain location

Innovation generates new products, processes, and services, which can create economic value and give a company a competitive edge in the market. However, innovating firms often fail to obtain significant economic returns from an innovation while imitators, customers, suppliers, and other industry participants benefit (Teece 1986). According to Pisano and Teece (2007), an innovator can improve returns on R&D (or capture a bigger slice of the pie) when it builds protective barriers either in the form of legal protection, such as patents, copyrights, or trade-secrets, or by other strategies such as investing in complementary assets, such as marketing, manufacturing, distribution channels, brand, and technologies.[1]

In general, software is an example of a technology that enjoys relatively strong legal protection, at least in countries where intellectual property rights are enforced (Pisano and Teece 2007). It is also not easy to imitate since the source code can be shielded from

[1] An innovator can also have natural barriers against imitation, for example, the difficulty of reverse engineering and tacitness of relevant technologies. Pisano and Teece (2007) refer to the protections afforded to innovators through both legal mechanisms (intellectual property protection) and natural barriers to imitation as "appropriability regime."

users and competitors. Thus, software companies such as Microsoft can gain significant economic value from innovation through protective mechanisms.[2]

However, there are many other types of innovations that do not enjoy such protective barriers. Even if innovations are guarded by legal protections such as patents, not every innovation contributes to economic returns. Namely, increased R&D spending can lead to more innovation activities, but it does not necessarily create more valuable innovations. In fact, the recent study of Booz Allen Hamilton (Jaruzelski, Dehoff, and Bordia 2006) shows that the number of patents (or patent counts) is not correlated to financial performance. Levin, Klevorick, Nelson, and Winter (1987) argue that appropriability conferred by a patent is not perfect; many patents can be circumvented and provide little protection because of stringent legal requirements for proof that they are valid or that they are being infringed. However, such a lack of protection does not necessarily increase competition if a firm establishes the brand name of a patented product. Investments in marketing, distribution, and customer service, which bestow brand reputation on a new product, can provide a company with some protection from competition and hence a greater advantage in increasing its returns (Bresnahan, Stern, and Trajtenberg, 1997).

In her study of global R&D sourcing in the information technology industry, Li (2006) argues that outsourcing firms (branded firms) can exploit most of the benefits of global economies of scale because they have relatively greater bargaining power than insourcing firms such as CMs and ODMs. Since an insourcing firm lacks brand reputation and international marketing know-how, it does not have an outside option, i.e., selling its own-brand products in the markets, if it breaches the outsourcing contract or disagrees with the terms that its outsourcing customers set. On the contrary, an outsourcing firm has brand reputation and international marketing know-how, and does not encounter any significant readjustment costs of R&D and production. Thus an outsourcing firm has an outside option of bringing its outsourcing activities back in-house, given that it has the same technology expertise as the insourcing firm does, although over time it may lose some of that knowledge internally. Additionally, an outsourcing firm adopts a multiple-supplier strategy and can switch to other suppliers at low cost through contract stipulation (Li, 2006).

In sum, in the global electronics industry, R&D can create economic value, but lead firms (or branded firms) can capture more benefits than non-lead firms because they focus more on building brands and marketing capabilities. These theoretical arguments lead to the following hypotheses:

Hypothesis 1: There is a positive relationship between R&D and firm performance.
Hypothesis 2: There is a positive relationship between being a lead firm and firm performance.

### 3.2 Complementarity of R&D and value chain location

[2] Microsoft also has benefited from the inability of others such as Apple to protect some of their innovations from Microsoft.

Innovators can capture significant economic returns from R&D when they have access to relevant complementary assets (or capabilities), which are required to successfully commercialize their innovation. In order to profit from innovation, firms must make R&D investment decisions based on the strategic analysis of markets and industries, and the firm's position within them. In the electronics industry, where manufacturers can provide a generic manufacturing capacity at a low cost, contractual and partnering strategies are ideal. While using contract manufacturers, branded electronics firms focus on system-level innovation, including concept design, as well as provision of other complementary assets, such as brand, marketing, and distribution channels, that are required for the commercial success of their technology innovations (Teece 1986, Pisano and Teece 2007).[3]

The resource-based view of the firm provides a theoretical framework to support the above viewpoint. By highlighting the importance of firm-specific resources for explaining firm performance, this model suggests that resources and capabilities can provide sustainable competitive advantages and lead to above-normal rates of return only when they are rare, valuable, inimitable, and non-substitutable (Barney 1991; Grant 1991; Wernerfelt, 1994). Resources include firms' tangible, intangible, and human resources while capabilities refer to a firm's ability to appropriately deploy, coordinate, and integrate its resources for productive activities (Coombs and Bierly 2006; Grant 1991; and Teece, Pisano, and Shuen 1997). R&D is a critical resource for gaining a competitive advantage. However, R&D does not necessarily lead to increased profit by itself. R&D spending can be wasted on products (or processes) unless the implementation of new products is successful (Coombs and Bierly 2006). In other words, supranormal profits may not be captured unless a firm builds complementary capabilities required to bring the new products to market successfully. Namely, firms can gain a significant value from R&D when they build a system (e.g., value chain) that integrates R&D more effectively with other relevant complementary assets (or capabilities), such as marketing, sales, brand, and a keen understanding of customer (or end-user) needs (Jaruzelski, Dehoff, and Bordia 2006).

The recent Global Innovation 1000 study of Booz Allen Hamilton (Jaruzelski, Dehoff, and Bordia 2006) shows that there are no significant statistical relationships between R&D spending and various measures of financial or corporate success.[4] Innovative firms distinguish themselves not by the amount they spend, but by the capabilities they demonstrate in ideation, project selection, development, or commercialization. The 2006 R&D scoreboard study of Department of Trade and Industry in the United Kingdom (DTI, 2007) also shows that in sectors where R&D is a key competitive factor, R&D is

[3] Teece (1986) argued that internal manufacturing capability was a key complementary asset. However, the use of contract manufacturers by lead firms has shown that manufacturing is not a differentiator in much of the electronics industry in recent years.

[4] Since 2005, Booz Allen Hamilton has studied the world's largest corporate R&D spenders annually to explore how companies can maximize their return on innovation investment. They rank 1,000 publicly traded corporations worldwide that spend the most on R&D (Global Innovation 1000). Based on the analysis of the 2005 data, the study suggests that there is simply no statistical relationship between R&D and most measures of financial performance. Gross margin (gross profits as a percentage of sales) is the only performance measure to which R&D has a significant positive relationship.

related to business success only when the right strategic choices are made and operations are managed well. Not all heavy R&D investors perform well because they make strategic errors, such as failing to balance R&D investment with investment in areas such as the development of brands, skills, new customers and markets, and establishing a global presence.

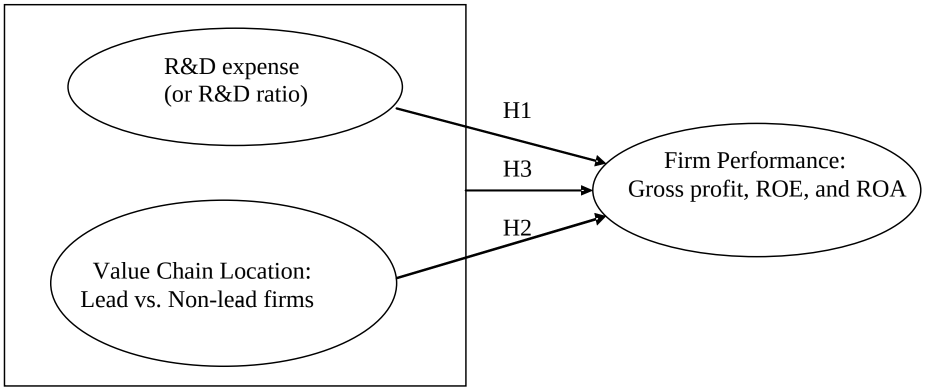
R&D is a necessary element of business success but not sufficient on its own. In order to make innovation successful, a firm must integrate R&D with other complementary assets or capabilities. Otherwise the cost of R&D may be greater than the benefits. In today's electronics industry where independent component suppliers, CMs and ODMs, and branded firms (or lead firms) form a global production network, a firm can capture more value from R&D when it commercializes its innovations successfully. Compared to component suppliers and CMs/ODMs, lead firms are positioned close to customers in the global value chain and have a well-known brand, better marketing and sales capabilities, and a keen understanding of customers. They can identify new product markets and design products that integrate advanced technologies to serve those markets by working closely with component suppliers and CMs/ODMs. Namely, compared to component suppliers and CMs/ODMs, lead firms can potentially obtain more value from R&D because they have complementary assets (or capabilities) needed for making their innovations a commercial success. Of course lead firms must bear higher costs of marketing and sales, so they must be able to capture enough value from their position in the supply chain to cover these costs. These theoretical arguments lead to the following hypothesis:

Hypothesis 3: There is a positive interaction effect between R&D and being a lead firm for firm performance.

The relationship between R&D and firm performance discussed in this section is depicted in Figure 2, which includes value chain location (lead versus non-lead firms) as a critical complementary factor for capturing a significant value from R&D.

In the following sections, we analyze empirically who benefits most from innovation in the global electronics industry.

Figure 2. R&D, Value Chain Location, and Firm Performance




Notes: Value chain location (lead versus non-lead firms such as component suppliers and CMs/ODMs) is the key to this model. By positioning itself close to customers in the global value chain, a lead firm can build capabilities complementary to R&D, by focusing on product design, brand, and sales and marketing. It also builds a keen understanding of customers' (or end users') needs and orchestrates the innovation process in the global value chain, thereby integrating advanced technologies into its products that customers find useful and usable.

## 4. Methodology and Model

In order to analyze the relationship of innovation and value chain location to firm performance, we conduct stepwise regression analysis of performance measures such as gross profit, return on equity (ROE), and return on assets (ROA), with R&D spending, a lead firm dummy variable, which indicates whether the firm is a lead firm or a non-lead firm, an interaction term for R&D spending and the lead firm dummy variable, and industry and region control variables. The interaction term examines if there is a complementary impact of R&D spending and being a lead firm on economic performance.

### 4.1 The model

Our model measures the value created and captured by firms in the global electronics production network (or value chain), such as lead firms and non-lead firms (CM/ODMs and component suppliers), while controlling for firm size, industry-, region-, and year-specific effects. We have four industry categories: computer, telecommunications, audio/video, and semiconductors, based on the North American Industry Classification System (NAICS). We have three regional categories: North America, Asia, and Europe.

$$V_{it} = \beta_0 + \beta_1 LF_{it} + \beta_2 R\&D_{it} + \beta_3 EMP_{it} + \beta_4 LF*R\&D_{it} + \beta_5 INDUSTRY_{it} + \beta_6 REGION_{it} + \beta_7 YEAR_{it} + \beta_8 LF*INDUSTRY_{it} + \beta_9 LF*REGION_{it} + \varepsilon$$

where for firm i in year t:

$V_{it}$ = Ln(gross profit), ROE, and ROA
$LF_{it}$ = A dummy for lead firm (being a lead firm)
$R\&D_{it}$ = Ln(R&D expense) or R&D ratio (R&D expense/sales)
$EMP_{it}$ = Ln (employees)
$LF*R\&D_{it}$ = Interaction term of lead firm and Ln(R&D expense) or R&D ratio
$INDUSTRY_{it}$ = a dummy for industry
$REGION_{it}$ = a dummy for region
$YEAR_{it}$ = a dummy for year
$LF*INDUSTRY_{it}$ = Interaction term of lead firm and industry
$LF*REGION_{it}$ = Interaction term of lead firm and region
$\varepsilon$ = an error term with zero mean

V stands for economic value; its measure will be replaced in turn by gross profit, ROE, and ROA. LF stands for lead firm, which is a dummy variable indicating whether the firm is a lead or non-lead firm. When gross profit is used as a dependent variable, R&D expense is employed in the model. The number of employees (EMP) is used as a control variable for firm size. We take the log of gross profit, R&D, and number of employees in order to get a normal distribution for those values.[5] When ROE, and ROA are used as dependent variables, R&D ratio (R&D expense/sales) is employed in the model. In order to control for region-, industry- and year specific effects, dummy variables for each region, industry, and year are included. The interaction term of R&D spending and being a lead firm is included in order to examine if there is a complementary impact of R&D and being a lead firm for economic performance. A positive sign may suggest that lead firms capture more value from R&D spending.[6] We also include the interaction terms of LF*INDUSTRY and LF*REGION in order to examine if the economic performance of lead firms differs across industries and regions.

### 4.2 Data sources and coding

The study employs two data sources: the Electronic Business (EB) 300 data set and the Hoovers database for the six years from 2000 to 2005. The EB 300 data set includes the top 300 electronics firms ranked by electronics revenue. The electronics revenue is derived from segmentation information and Reed Research estimates. It includes revenue from the sale, service, license or rental of electronics/computer equipment, software or components. Data items such as sales, cost of goods sold (COGS), return on equity (ROE), return on assets (ROA), R&D expense, and the number of employees are obtained from the Hoovers database for the same firm included in the EB 300 data set.

[5] The log transformation has brought the distribution closer to normal by greatly reducing the skewness. We do not make the log transformation for ROE, and ROA because they are normalized by taking a ratio value.
[6] Value captured by firms can be estimated by gross profit, the difference between net sales and cost of goods sold. Gross profit does not equal value added since it excludes direct labor. Instead it measures the value a company captures from its role in the value chain, which it can use to reward shareholders (dividends), invest in future growth (R&D), cover the cost of capital depreciation, and pay its overhead expenses (marketing and administration) (Dedrick, Kraemer, and Linden 2007; Linden, Kraemer, and Dedrick 2007).

The EB 300 data set includes 420 different firms for the six-year period. Since we focus on three types of firms in the global electronics industry as lead firms, CMs/ODMs, and component suppliers, we select only the firms operating in the following four industries: the computer and peripheral equipment manufacturing, communications equipment manufacturing, audio and video equipment manufacturing, and semiconductor and other electronic component manufacturing. The selection is based on the four-digit North American Industry Classification System (NAICS) code. The NAICS codes for the above four industries are 3341, 3342, 3343, and 3344 respectively.

We exclude firms with revenue from areas other than electronics. The resulting number of selected firms is 200. We code these firms as lead firms, CM/ODMs, and component suppliers. Lead firms are branded firms at the head of a supply chain and closest to distribution and retail. We exclude firms if they cannot be classified as pure lead firm, CM/ODM, or component supplier. This selection process reduces the number of firms in the final data set to 151. The coding process is conducted by the authors. Agreement (or inter-rater reliability) among the coders is assessed by the Cohen's kappa.[7] The kappa statistics are .637, .579, and .511, all of which are statistically significant at a level of .001. The results indicate that our coding is highly reliable.

The sample includes 738 observations for the six years from 2000 to 2005. The sample statistics are shown in Table 1.

= = Insert Table 1 here = =

## 5. Results

### 5.1 Results for gross profit (value capture)

Table 2 presents the results of stepwise regression analyses for gross profit. The F statistics are significant for all three models (Models 1, 2, and 3), and the change in $R^2$ is also significant when the interaction term of R&D spending and lead firm is added (Model 2). R&D spending is positively associated with gross profit, and the positive relationship is significant. The estimate is consistent with hypothesis 1 that there is a positive relationship between R&D and firm performance. The null hypothesis of zero effect can be rejected at a confidence level of .001.

Being a lead firm also has a significant relationship to gross profit (Model 1). The estimate supports hypothesis 2. However, when the interaction term of R&D spending and lead firm is added (Model 2), the main effect of being a lead firm becomes weak. Instead, the interaction effect of R&D and lead firm is significant: it is positively associated with gross profit, and the positive relationship is significant at a level of .05. Since the interaction effect is greater than the main effect of lead firm, we exclude the

[7] Cohen's kappa measures the agreement between the evaluations of two raters when both are rating the same object. A value of 1 indicates perfect agreement. A value of 0 indicates that agreement is no better than chance (Cohen 1960). We get three kappa statistics because there are three raters.

main effect of lead firm from Model 2 (Model 3). The results show that the change in $R^2$ is not significant, which indicates the insignificance of the main effect of lead firm, and that the interaction effect of R&D and lead firm is positive and significant. The coefficients of the interaction term in Models 2 and 3 supports hypothesis 3 that there is a positive interaction effect between R&D and being a lead firm for gross profit.

The results indicate that, on average, firms spending more on R&D have higher gross profits. However, the relationship of R&D to performance may be moderated by a firm's position in the value chain; that is, lead firms can achieve higher margins from R&D than CMs and ODMs, and component suppliers. In other words, lead firms can leverage their positional (or strategic) advantage by increasing R&D spending. Component suppliers often invest heavily in R&D and pursue high levels of innovation compared to lead firms. However, our results indicate that lead firms obtain more value from R&D than component suppliers. Lead firms are positioned close to the consumer market in the global supply chain, and invest heavily in marketing and brand building in order to make their products more visible (Jacobides, Knudsen, and Augier 2006).[8] The question is whether the lead firms are able to capture enough value to cover those marketing costs and translate their higher margins into better bottom-line financial performance, which we address in the analysis of ROA and ROE.

The coefficient of employees indicates that larger firms capture more value than smaller ones. Large firms are more likely to possess resources and capabilities already in place within their boundaries, which are required for successful commercialization of their innovations (Teece 1986). Thus, they can do a better job of getting more value from the introduction of new products to market. The year dummy variables show that firms generate significantly less value in 2001 and 2002, compared to 2000 (the base year). The result might reflect the economic recession brought by the dot.com crash in 2001.

The performance of lead firms as measured by gross profit (value capture) is not significantly different between North America and Asia. However, lead firms in Europe capture somewhat more value than those in North America – the estimate of the interaction term of lead firm and Europe is positive and significant at a level of .10 (Models 2 and 3). Lead firms in the computer industry capture greater value than those in the telecommunications industry – the estimate of the interaction term of lead firm and the telecommunications industry is negative and significant at a level of .001.[9] One reason might be that the telecommunications industry is more heavily regulated than the computer industry. Another reason might be that the dot.com bust hit telecommunications equipment market leaders, such as Nortel and Lucent, harder than computer companies, and they recovered more slowly than computer companies.

= = Insert Table 2 here = =

[8] Our data (Table 1) show that lead firms spend more on selling, general, and administrative (SG&A) expense than non-lead firms, which includes marketing and administration expenses.
[9] There are no lead firms in the semiconductor industry. Thus we do not include the interaction term of lead firm and the semiconductor industry in the model.

### 5.2 Results for ROE and ROA

The results in Table 3 show that R&D spending has no significant relationship to firm performance as measured by ROE and ROA. On the other hand, being a lead firm is strongly associated with a higher ROE, but not with ROA (Model 1). The estimates of being a lead firm for both performance measures are significant at levels of .01 and .05 respectively when the interaction term of R&D with lead firm is introduced (Model 2). This indicates that lead firms have higher ROE and ROA than CMs and ODMs, and component suppliers. The interaction term of R&D spending and being a lead firm actually shows a weak negative relationship to ROE and ROA. Unlike the results for gross profit, these results might indicate that benefits obtained from R&D are trivial for lead firms. In order to capture more value from R&D, lead firms have to spend money on market research, sales and marketing, branding, advertising, etc. Hence, benefits obtained from R&D, as measured by ROE and ROA, can decrease because these costs can cancel out the benefits.

The results also show that lead firms in North America earn higher ROE and ROA than those in Asia (Model 2). One possible reason is that lead firms in Asia, such as Taiwanese and Korean firms, started as CMs or ODMs and are in the early stage of transforming themselves into lead firms.[10] Thus, they are not yet capturing as much value as lead firms in North America. Unlike the other analyses, lead firms' performance as measured by ROE and ROA is not significantly different across industries.

= = Insert Table 3 here = =

## 6. Discussion and Conclusions

Value created from innovation is distributed not only to the lead firms, but also to other firms in the supply chain. In order to better understand who benefits most from innovation in the global electronics industry, this research examines the relationship of R&D spending and value chain location (lead versus non-lead firms) to firm performance. We employ multiple firm performance measures such as gross profit, ROE, and ROA.

Our results show that firms spending more on R&D create a higher value as measured by gross profit, but do not improve ROE and ROA. These findings are consistent with the recent study by Jaruzelski, Dehoff, and Bordia (2006). There is a strong positive

[10] Acer, a Taiwanese lead firm, for example, was a contract manufacturer during the 1980s. The company launched aggressive organizational transformations during the 1990s by integrating backward into R&D activities and forward into marketing and distribution (Yeung 2006). Unlike Taiwanese and Korean lead firms, most Japanese lead firms did not go through the stage of CMs or ODMs. However, U.S. lead firms might have more skills and experience in marketing and branding than Japanese lead firms.

relationship between lead firms and gross profit, ROE and ROA, but the relationship between lead firms and gross profit becomes insignificant when the interaction term of R&D and lead firm is included in the analysis. These findings indicate that the relationship between value chain position and performance is significant on most measures; that is, lead firms obtain more value than CMs and ODMs, and component suppliers. Finally, there is a positive interaction effect of lead firm status on the relationship between R&D and gross profit.

These findings suggest that the relationship of R&D to performance is mixed and may be moderated by position in the value chain; that is, lead firms can capture higher value (gross profit) from R&D than CMs, ODMs, and component suppliers, but that these higher margins do not necessarily translate into better ROE and ROA. Possibly the R&D conducted by lead firms to differentiate their products is not what gives them an overall advantage compared to others in the supply chain, but their advantage comes from branding, marketing and other activities.

In today's global electronics industry, lead firms are system integrators. Overseeing the innovation process over the global value chain, they collaborate with CMs/ODMs to bring new products to market by incorporating new technologies developed by component suppliers. By positioning themselves close to the market, lead firms innovate by identifying products that meet customers' needs. Additionally, they focus on brand development, marketing, and sales. R&D is a core activity of the innovation process in the global electronics industry. R&D can create value, but lead firms can capture higher margin from their innovations than other value chain participants, such as CMs/ODMs and components suppliers, due to their unique resources and capabilities, which others do not have. System integration, product design, branding, and market development are all critical complementary capabilities that can help electronics firms improve their financial performance, but not necessarily the returns to R&D.

This study is not free from limitations. First, it focuses on lead firms and non-lead firms such as CMs/ODMs and component suppliers. The present study does not consider other participants in the global electronics industry, such as distributors and retailers. It also does not distinguish hardware and software component suppliers. Since they are positioned at different levels of the value chain, it would be interesting for future studies to consider them separately. Another limitation is that the explained variance ($R^2$) of the results for ROE and ROA is relatively low, compared to the results for gross profit, although this is not surprising as many other factors can contribute to a firm's return on equity and assets. This indicates that there might be some missing variables in the model. Although we control industry and regional economy in our analysis, there might be other industry- and economy-specific factors that can affect firm performance. However, we do not include all such variables because this study focuses on the relationship between R&D and firm performance (value creation) and the importance of value chain location for capturing more value from R&D.

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Table 1. Sample Statistics (2000 to 2005)

| Variables | Lead firms | | | Non-Lead firms | | | Full Sample | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | St. Dev. | Obs. | Mean | St. Dev. | Obs. | Mean | St. Dev. | Obs. |
| Sales (millions) | 11,479.3 | 15.8 | 239 | 4,205.6 | 5,070.5 | 499 | 6,561.2 | 10,483.6 | 738 |
| R&D expense (millions) | 1,169.2 | 1,438.4 | 159 | 376.5 | 695.9 | 280 | 662.5 | 1,094.4 | 439 |
| R&D ratio (R&D/Sales) | 8.36% | 5.72% | 159 | 9.58% | 8.07% | 280 | 9.14% | 7.32% | 439 |
| Employees (thousands) | 35.1 | 36.0 | 192 | 20.4 | 23.3 | 432 | 24.9 | 28.6 | 624 |
| Gross profit (millions) | 4,432.0 | 5,216.3 | 195 | 1,269.1 | 2,583.9 | 430 | 2,255.9 | 3,898.8 | 625 |
| Gross margin (%) | 34.7% | 18.9% | 195 | 28.2% | 20.1% | 430 | 30.2% | 20.0% | 625 |
| ROE (%) | -3.05% | 140.7% | 197 | -1.62% | 82.2% | 455 | -2.05% | 103.3% | 652 |
| ROA (%) | 1.77% | 17.3% | 198 | 1.0% | 25.8% | 468 | 1.23% | 23.6% | 666 |
| SG&A costs (% of sales) | 18.3% | 8.29% | 191 | 10.3% | 6.93% | 425 | 12.8% | 8.24% | 616 |

Table 2. Regression Results for Gross Profit

| Variable | Ln(Gross Profit) | | |
|---|---|---|---|
| | Model 1 | Model 2 | Model 3 |
| Ln(R&D Expense) | .59***[1] (18.78)[2] | .55*** (15.46) | .55*** (16.74) |
| Lead Firm | .34*** (7.16) | .03 (.80) | |
| Ln(Employee) | .32*** (10.90) | .29*** (9.00) | .28*** (9.49) |
| Asia | -.04(-1.29) | -.05(-1.40) | -.05(-1.45) |
| Europe | -.09* (-2.20) | -.07+ (-1.92) | -.07+ (-1.91) |
| Asia*Lead Firm | -.01 (-.32) | .02 (.66) | .03 (.88) |
| Europe*Lead Firm | .08* (2.01) | .07+ (1.66) | .07+ (1.65) |
| Telecom | .34*** (5.00) | .34*** (5.00) | .34*** (5.00) |
| Audio/Video | .03 (.56) | .03 (.47) | .03 (.45) |
| Semiconductor | .12** (2.95) | .12** (3.07) | .12** (3.08) |
| Telecom*Lead Firm | -.45*** (-6.15) | -.46*** (-6.40) | -.46*** (-6.40) |
| Audio/Video*Lead Firm | -.07 (-1.26) | -.05 (-.96) | -.05 (-.93) |
| Year 2005 | -.04 (-1.34) | -.04 (-1.24) | -.04 (-1.24) |
| Year 2004 | .01 (.23) | .01 (.21) | .01 (.20) |
| Year 2003 | -.05 (-1.48) | -.05 (-1.53) | -.05 (-1.53) |
| Year 2002 | -.10** (-3.10) | -.10** (-3.06) | -.09** (-3.06) |
| Year 2001 | -.08* (-2.47) | -.08** (-2.60) | -.08** (-2.62) |
| Ln(R&D Expense)*Lead Firm | | .35*(2.46) | .38***(7.62) |
| $R^2$ | 76.5% | 76.8% | 76.8% |
| $R^2$ Change | | .004* | .000 |
| F | 70.3*** | 67.6*** | 71.8*** |
| N | 386 | 386 | 386 |

Key: *** (p<.001), ** (p<.01), * (p<.05), + (p<.10)

[1] Standardized coefficients are reported. [2] The values in parentheses are t-statistics.

Table 3. Regression Results for ROE and ROA

| Variable | ROE | | ROA | |
|---|---|---|---|---|
| | Model1 | Model 2 | Model 1 | Model 2 |
| R&D Ratio (R&D Expense/Sales) | -.06[1] (-1.05)[2] | -.02 (-.32) | -.08 (-1.28) | -.03 (-.42) |
| Lead Firm | .25** (2.71) | .39** (3.13) | .15 (1.62) | .30* (2.51) |
| Ln(Employee) | -.04 (-.69) | -.03 (-.50) | -.05 (-.94) | -.04 (-.73) |
| Asia | .06(.90) | .08 (1.15) | .05 (.70) | .07 (1.00) |
| Europe | .04 (.54) | .04 (.54) | .05 (.64) | .05 (.64) |
| Asia*Lead Firm | -.10 (-1.58) | -.15* (-2.13) | -.10 (-1.59) | -.15* (-2.27) |
| Europe*Lead Firm | .01 (.17) | .01 (.13) | .02 (.23) | .02 (.19) |
| Telecom | .16 (1.19) | .16 (1.16) | .10 (.77) | .10 (.73) |
| Audio/Video | .02 (.20) | .02 (.19) | -.01 (-.08) | -.01 (-.10) |
| Semiconductor | $.16^{+}$ (1.93) | $.15^{+}$ (1.79) | .02 (.21) | .00 (.04) |
| Telecom*Lead Firm | $-.25^{+}$ (-1.73) | -.19 (-1.29) | -.19 (-1.34) | -.12 (-.85) |
| Audio/Video*Lead Firm | -.06 (-.57) | -.06 (-.58) | .00 (.00) | -.00 (-.01) |
| Year 2005 | -.001 (-.01) | -.001 (-.02) | -.01 (-.14) | -.01 (-.15) |
| Year 2004 | .001 (.01) | .004 (.06) | -.02 (-.28) | -.01 (-.22) |
| Year 2003 | -.04 (-.63) | -.03 (-.55) | -.07 (-1.09) | -.06 (-.99) |
| Year 2002 | -.05 (-.74) | -.04 (-.64) | $-.12^{+}$ (-1.89) | $-.11^{+}$ (-1.78) |
| Year 2001 | -.26*** (-4.32) | -.26*** (-4.25) | -.30*** (-4.87) | -.29*** (-4.80) |
| R&D Ratio*Lead Firm | | $-.19^{+}$ (-1.65) | | $-.23^{+}$ (-1.95) |
| $R^2$ | 9.9% | 10.6% | 11.3% | 12.2% |
| $R^2$ Change | | $.007^{+}$ | | $.009^{+}$ |
| F | 2.39** | 2.42** | 2.80*** | 2.88*** |
| N | 387 | 387 | 391 | 391 |

Key: *** ($p<.001$), ** ($p<.01$), * ($p<.05$), $^{+}$ ($p<.10$)

[1] Standardized coefficients are reported. [2] The values in parentheses are t-statistics.