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Institutional Support, Regional Trade Linkages and Technological Capabilities in the Semiconductor Industry in Malaysia[*]

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Abstract: *This article examines the relationship between host-site institutional support and regional trade linkages on firm-level technological capabilities in the semiconductor industry in Malaysia. An evolutionary perspective was used to measure technological capabilities using knowledge embodied in machinery, organization, processes and products. The results show that host-site institutional support, and regional trade linkages were correlated with technological upgrading. The relationship between host-site institutional support and technological upgrading was stronger than that between regional trade linkages and technological upgrading. The results show that host site institutional support is more important than regional integration in influencing firms' capacity to upgrade their technological capabilities.*

Keywords: institutional support, Malaysia, regional trade chains, semiconductors, technological capabilities

JEL Classification: L62, L22, L14, O31

1. Introduction

Semiconductor firms became the first large wave of electronics firms to relocate in Malaysia when National Semiconductor built its factory at the Bayan Lepas Free Trade Zone in Penang in 1971 before commencing export-oriented production in 1972. By the mid-1970s Intel, Advanced Micro Devices, Texas Instruments, Hitachi, Motorola and Siemens (Litronix) had relocated massive assembly operations in Malaysia. Whereas Motorola and Siemens have since sold the semiconductor plants to Freescale and Qimonda respectively, Hitachi has transformed to Renesas and National Semiconductor acquired the brand name of Fairchild. Thus, most foreign semiconductor firms have retained operations in Malaysia. While the older firms have remained the other semiconductor firms to relocate in Malaysia since 1990 include Integrated Device Technology, Infineon, ST Microelectronics, Unisem, Carsem, Globetronix, Silterra, 1st Silicon, Avago, Alterra, Osram and ON Semiconductor.

Although the government started the Malaysian Institute of Microelectronics Systems (MIMOS) in 1985 to support the development of national semiconductor firms, it was not until 1995 that the first serious initiative began when the first national wafer fabrication plant was incubated from MIMOS. Government efforts to support functional upgrading, i.e. integration of high value added operations such as wafer fabrication, chip design, R&D and R&D support following the launching of the Action Plan for Industrial Technology Development (APITD) in 1991. Silterra was launched at Kulim High Tech Park in 2000 to fabricate wafers using the Taiwanese framework of buyer-supplier alliances. Meanwhile Carsem, Unisem and Globetronics emerged as private Malaysian firms with their managements dominated by former employees of foreign semiconductor MNCs in Malaysia. The government also extended the provision of grants to foreign firms in 2005, which helped attract wafer fabrication plants from Infineon, ON Semiconductor and Osram since 2005.

In light of the questions posed in the introduction to this special issue, this article seeks to test the hypotheses: one, institutions in support for high tech activities are positively correlated with firm-level technological capabilities and two, regional production chains are positively correlated with technological capabilities. The rest of the article is organized as follows. Section 2 discusses the importance of the semiconductor industry to the Malaysian economy. Section 3 reviews past literature on technological upgrading in the semiconductor industry in Malaysia. Section 4 presented the methodology and data used in testing the two

hypotheses. Section 5 evaluates the importance of institutional support and regional trade links on technological capabilities. Section 6 finishes with the conclusions.

2. Why the Semiconductor Industry in Malaysia?

Three reasons explain why the semiconductor industry of Malaysia provides an excellent empirical laboratory analyse the influence of institutional support and regional trade chains on technological capabilities. Firstly, the semiconductor industry initiated the first two waves of foreign MNC relocations in Malaysia from abroad, 1972-74 and 1979-81 to act as the springboard for the expansion of the electronics industry, which has dominated manufacturing in the country since the 1980s. Secondly, the government of Malaysia identified semiconductors among its strategic industries or promotion since 1986. Thirdly, Malaysia has been among the world's leading exporters of integrated circuits since the early 1970s (UNCTC, 1986; WTO, 2012).

2.1. Importance to the national economy

In the absence of consistent data on employment in the semiconductor industry, we chose to use the electronics industry to demonstrate the importance of the industry to the national economy. The industry's contribution to manufacturing employment reached its peak in 2000 of 30.5 percent before falling to 20 percent in 2010 (see Table 1). Its contribution to manufacturing value added rose to 24.6 percent in 2000 before falling to 20.0 percent in 2010. In other words, the electronics industry accounted for 20 percent of Malaysia's manufacturing employment and value added in 2010.

**Table 1. Contribution of electronics in manufacturing, Malaysia, 1990-2010**

Year	Employment	Value Added (US$ Millions)	% in Manufacturing Employment	% in Manufacturing Value Added
1990	217,600	1,952.1	25.8	21.5
2000	480,800	6,854.0	30.5	24.6
2010	375,800	34,062.9	20.0	20.0

Note: *Converted based on historical exchange rates.
Source: Malaysia Department of Statistics (2010; 2011; 2012).

The share of semiconductor exports in overall national exports of Malaysia gradually fell from 24.9 percent in 1990 to 22.4 percent in 2000 and 21.3 percent in 2011 (see Figure 1). Malaysia accounted for 7.7 percent of global semiconductor exports in 1990. This share fell gently to 6.1 percent in 2000 before rising again to 7.1 percent in 2011 (see Figure 1). Hence, the industry has remained important in the Malaysian economy.

Figure 1. Share in exports, semiconductors, Malaysia, 1990-2011
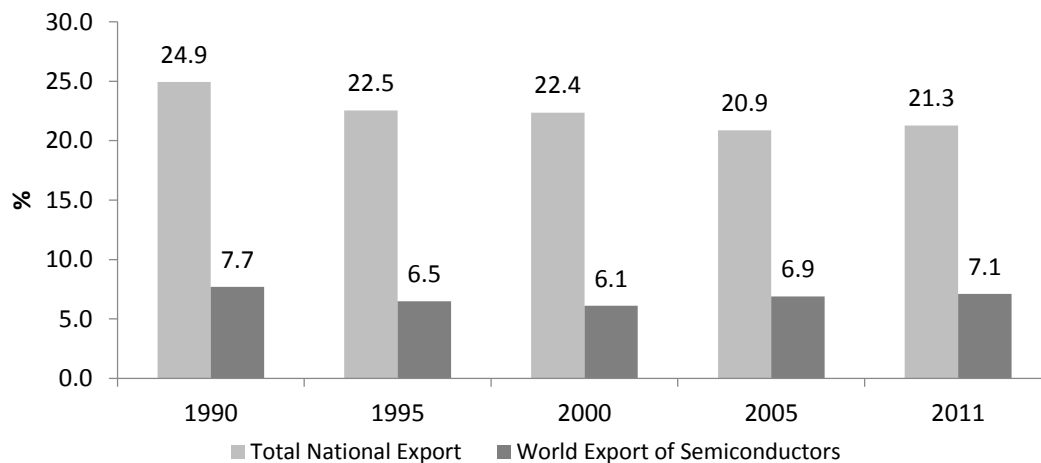
Source: Computed from WTO (various issues); Bank Negara Malaysia (various issues).

Exports and imports of electronics components from and to Malaysia respectively rose strongly over the period 1990-2011 (see Table 2). The trade balance coefficient of semiconductors fell from -0.04 in 1990 to -0.15 in 2000 before rising to 0.05 in 2011. The revealed comparative advantage of the industry remained strong, rising from 29.8 in 1990 to 36.8 in 2000 before falling to 25.3 in 2011.

Table 2. Trade indicators, semiconductors, Malaysia, 1990-2011

Year	1990	1995	2000	2005	2011
Exports[*]	5.2	16.3	24.1	33.6	46.1
Imports[*]	5.7	21.5	32.4	37.1	41.7
TB[#]	-0.04	-0.14	-0.15	-0.05	0.05
RCA	29.8	31.1	36.8	34.8	25.3

Note: [*] - in billions; [#] - measured using the formula (exports-imports)/ (exports+imports); RCA – revealed comparative advantage - measured by dividing the share of exports of semiconductors in overall national exports with its share in global semiconductor exports.
Source: Computed from WTO (various issues); COMTRADE (2012); Bank Negara Malaysia.

2.2. Government Promotion

The first batch of semiconductor firms relocated assembly activities from the United States, Japan and Europe following government efforts to attract labour-intensive investment through the launching of the Second Malaysia Plan in 1971 to generate jobs (Malaysia, 1971). Free Trade Zones (FTZs) were opened in strategic locations from 1972 to offer export-oriented firms security, tariff-free operations, good basic infrastructure and subsidized land. Pioneer status and investment tax credits were also attractive instruments that the government offered for large export-oriented investments.[1] Foreign firms were allowed total foreign ownership if they targeted their output mainly to export markets. The English-educated labour force offered foreign MNCs the additional benefits vis-à-vis their home sites to relocate in Malaysia.[2]

The government launched a second round of import-substitution in 1981 targeted at promoting national heavy industries *a la* Korea and Japan, which was popularly framed as the Look East Policy. Between 1981-85, export-oriented MNCs (including foreign semiconductor firms) faced uncertainty as their efforts to seek tax holidays extended upon maturity were not approved (Rasiah, 1988). The government changed its position in 1986 to renew incentives to foreign export-oriented MNCs following a recession when GDP growth hit negative figures and unemployment began to rise. The government also devalued the Ringgit to attract foreign direct investment. The whole of market-friendly Southeast Asia also benefited from external developments. The Plaza Accord of 1985 (which saw the

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[1] These incentives were available since the enactment of the Investment Incentives Act in 1968 (Malaysia, 1971).
[2] The Industrial Coordination Act of 1975 narrowed the provision of tax free holidays and total foreign ownership to firms exporting at least 80% of output (Malaysia, 1976).

appreciation of currencies of Won, New Taiwan dollar, the Singapore dollar and the Yen), and the withdrawal of the generalized system of preferences (GSP) from Korea, Taiwan and Singapore in February 1988 attracted massive investment inflows from East Asia to the market-friendly Southeast Asian countries. Malaysia was a big beneficiary. The mid-1980s crisis drove firms to quicken the replacement of old technologies with new technologies, especially massive improvements in production technologies (Rasiah, 1988).

The labour market became saturated as a consequence of the rapid expansion of FDI inflows so much so that foreign labour became an important source of hiring. The saturated labour market also drove the government to launch the APITD in 1991. A wide range of meso organizations were created to stimulate technological upgrading in the country. The Human Resource Development Council, the Malaysian Technology Development Corporation, the Malaysia Industry-Government High Technology and the Multimedia Super Corridor were some of them launched in the 1990s. The MIMOS was also corporatized in the 1990s. The national firms of Silterra and 1st Silicon, first incubated at MIMOS, were started to fabricate wafers since 2000. Also, grants were also offered to support R&D activities, though, the focus of grants was confined to national firms until 2005. The old firms of Motorola, Intel, Advanced Micro Devices and Renesas (Hitachi) and the newer firms of Alterra, Avago, Infineon, Osram and Onn Semiconductor were extended grants to undertake high technology activities. Hence, the semiconductor industry began to enjoy chip design, wafer fabrication and R&D support for the first time since 2000.

When the semiconductor industry first arrived in Malaysia all output were exported back to parent plants before they were exported to their target destinations. Exports direct to the destinations began in the 1980s following rapid growth in the East Asian market. Japan, Korea, Taiwan and Singapore were the early target of direct exports. The government took advantage of these firm-level developments to promote further direct exports so as to attract higher value added activities to Malaysia since the promulgation of the Promotion of Incentives Act of 1986 (Malaysia, 1986). With the proliferation of independent wafer fabrication and fabless semiconductor firms' inputs too increasingly arrived from East Asia making regional production networks important from the 1990s.

3. Theoretical Considerations

The two key relationships we seek to examine in this article are the influence of host-site institutional support facilities on technological capabilities (TC), and the influence of regional trade linkages (RL) on technological capabilities. While the former is little tested in the developing regions, the latter is important because of the growing importance of East Asia in global economic growth. The concepts of TC and RL have been defined in Rasiah, Kimura and Oum (2014). In doing so we have avoided somewhat from examining the much researched link between exports and technological capabilities there is considerable work already in that field (see Rasiah, 2010), which nevertheless, is also captured strongly in the link between TC and RL

3.1. Host-site Institutional Support and Technological Capabilities

The importance of host-site institutional support to stimulate the upgrading of technological capabilities was first discussed by industrial policy exponents (Smith, 1776; Hamilton, 1791; List, 1885). North (1991) referred to institutions as the 'rules of the game' and organizations and entrepreneurs as 'the players'. Williamson (1985) associated institutions with "governing structures" that mould economic activity, like a nation's financial "institutions", or the way firms tend to be organized and managed.

Host-site institutions and meso organizations associated with generating and stimulating knowledge flows are critical to attract the relocation of high tech firms or for existing firms to upgrade technological capabilities. In the developed countries of United States, Germany and Japan, and the recently developed countries of South Korea, Taiwan and Singapore, the government is a major financier of public goods, including knowledge generation through the provision of R&D grants (OECD, 2013).

Where foreign multinationals have stimulated technology transfer to national firms, they are unlikely to relocate frontier R&D activities at host sites unless it involves the exploration or development of rare host-site resources, or when the host site is endowed with strong research-based universities. Also, there is evidence of multinationals undertaking R&D in pharmaceuticals in the developing economies owing to the availability of rare flora and human capital, and off-shoring of electronics R&D to benefit from strong high tech support institutions in Taiwan (Ernst, 2006). Motives of multinationals matter in such relocation decisions (Cantwell and Mudambi, 2005). Also, in the integrated circuits industry there is only evidence of MNCs' frontier R&D activities being relocated at host-sites endowed with

strong research universities, e.g. Samsung Semiconductor and Taiwan Semiconductor Manufacturing Company in the United States (Gartner, 2013).

Although employees in firms gain significant knowledge through training and learning by doing in firms (Marshall, 1890; Penrose, 1959), universities and R&D laboratories are important nodes of knowledge that firms access through hiring graduates, contract training projects and R&D activities. Especially in high tech industries firms rely extensively on hiring competent engineers and scientists to carry out R&D and commercialization activities (Nelson, 1993).

While it is important that host-site organizations participate in generating knowledge, it is also critical that they are cohesively integrated with firms (Mytelka, 2001). Nelson (2008), Lundvall (1988) and Edquist (2004) addressed the importance of interdependent and interactive links between firms and organizations. Connectivity and coordination is critical for knowledge flows – beyond simply codified information that markets can coordinate. The focus is really on technological capabilities that are evolved in firms through linkages with high tech organizations such as training institutes, standards organizations and R&D laboratories. Thus, we hypothesize that firm-level TC is correlated with host-site HI.

3.2. Regional Trade Linkages and Technological Capabilities

The rapid expansion of East Asia has attracted a number of theories on regional trade linkages. Regional trade and investment linkages in East Asia can be first traced to Akamatsu (1962). Subsequently, Krugman's (1991) work on the new geography that discusses economic integration and its effects on growth synergies has become important.

Akamatsu (1962) had pioneered the first regional trade and investment linkages theory using the flight of a flock of geese to explain economic growth and structural change (see Rasiah, Kimura and Oum, 2015). While this regional model did explain the movement of investment and the direction of trade sequentially for a while, the supplanting of the leading goose by the following Korean and Taiwanese geese (e.g. Samsung and Taiwan Manufacturing Semiconductor Corporation) undermined its usefulness. Nevertheless, the basic underlying rationale of regional economic integration and its effect on integrating economies is still relevant today.

The new geography argument advanced by Krugman (1991) that explains economic growth on the basis of geographical proximity as economies become increasingly more integrated has also raised the importance of regional trade linkages in economic growth. Subsequently, the World Bank (2009) took on this new geography argument for its World

Development Report. We examine if the growing regional trade linkages also influence the development of firm-level technological capabilities. The World Bank (2009) used this argument to focus on cities as a major driver of economic synergies.

Although technological advance and increasing loosening of borders have made global trade and investment faster and cheaper, geographical distance have continued to play a role in ensuring that in some regions increased integration has generated stronger trade and investment growth. Continuous economic integration in the ASEAN Free Trade Area (AFTA), and the greater ASEAN members of China, Japan, South Korea and Taiwan has been driven considerably by all the governments of these countries. Hence, it is worth testing if the growing RL is reflected in the TC of especially countries still in the lower rungs of the technology ladder, such as, Malaysia.

3.3. Past Research Works on Malaysia

Work on technology development in the semiconductor industry in Malaysia can be traced to the proliferation of product and process technologies in MNCs, technology diffusion from foreign MNCs to national firms, government efforts through incentives, levies and grants to stimulate technological upgrading, and the impact of technological capabilities on firm performance.

From the early works on the semiconductor industry in Malaysia argued that semiconductor firms in Malaysia were perpetuating the exploitation of workers without significant upgrading (see Lim, 1978; Salih and Young, 1987). However, these works hardly examined the dynamics of technology in the semiconductor firms. More recent works Rasiah (1988,), Hobday (1995) and Mathews and Cho (2000), provided a more incisive account of technological upgrading in the industry through examining both anecdotally (see also Rasiah, 1988; Hobday, 1995; Mathews and Cho, 2000) and econometrically the impact of technological change and upgrading on economic performance (see also Lai and Narayanan, 1999) in the semiconductor industry in Malaysia.

Using a snowballing research framework, Rasiah (1994) showed significant upgrading in process and production technology in foreign semiconductor multinationals with considerable diffusion to national firms. Hobday (1995) showed evidence of incremental innovation in multinationals in East Asia with Malaysia as one of the examples. Mathews and Cho showed evidence of the upward movement of semiconductor firms in the technology ladder. However, Rasiah (2010) argued that technical change and the

development of national firms has been slow primarily because of the lack of human capital and adequate institutional support.

Lai and Narayanan (1999) and Rasiah (2010) presented econometric evidence on the positive impact of technological capabilities on export performance. Rasiah (1994) and Lai and Narayanan (1999) offered evidence on the development of national suppliers in Penang that has evolved largely without direct involvement of the government. While acknowledging the positive link between exports and technological capabilities, and the development of national suppliers, these works also cautioned that such developments have been confined to low end activities primarily because of serious human capital shortages and lack of institutional support.

Despite the significance of the above past works, two questions on technological upgrading remains inadequately addressed so far. Firstly, whether the introduction of high tech institutional support (provision of grants, efforts to attract R&D scientists and engineers from abroad, and initiatives to link firms with research universities in the country, which has emerged since 2005) has translated into technological upgrading. Secondly, linking with production sites in East Asia has resulted in technological upgrading in Malaysia. Thus, we seek to analyse econometrically these two questions here.

4. Methodology and Data

Taking the cue from the introduction (Rasiah, Kimura, and Oum, 2015), the exercise focuses on answering the questions of whether host-site institutional support matters to explain technological upgrading, and whether regional trade linkages are important in firms' technological upgrading. As review in the previous section shows no works have examined robustly these relationships on the semiconductor industry in Malaysia. Hence, the analytic framework focuses directly on the statistical relationships between high tech institutional support and technological capability, and between regional trade linkages and technological capability. The dependent variable examined in this article is technological capability. In the first the focus is on examining the influence of host-site institutional support on technological capabilities, while in the second the focus is on the influence of regional trade linkages on technological capability.

4.1. Specification of Variables

The variables for examining the statistical relationships are specified in this section.

4.1.1. Dependent Variable

Technological capability (*TC*) was estimated using the following 6 proxies:

$$TC - F\ (CIQT,\ AC,\ PD,\ RD,\ TE,\ PAT)$$

Where *CIQT* refers to cutting-edge inventory and quality control techniques (*CIQT*) of statistical process control (*SPC*), quality control circles (*QCC*), any one of the international standards organization (*ISO*) series, total preventive maintenance (*TPM*), integrated materials resource planning (*MRP2*) and total quality management (*TQM*). A score of 1 was added for presence of each of these techniques; *AC* refers to the presence of adaptive capabilities (*AC*) on processes, layouts, machinery and products. A score of 1 was added for the presence of each of them; *PD* refers to the presence of product development (*PD*) which is counted as 1 if it exists and 0 otherwise; *RD* refers to R&D expenditure as a share of sales; *TE* refers to training expenditure as a share of payroll; *PAT* refers to the number of patents taken in the United States. The normalization formula $(X_i - X_{min})/(X_{max} - X_{min})$ was used to convert each of the 6 proxies to the range of 0-1 before they are added; X_i, X_{min} and X_{max} refers to the observed, minimum and maximum values respectively.

4.1.2. Explanatory Variables

High tech institutional (*HI*) support was estimated using the following 4 proxies:

$$HI - F\ (RDG,\ RU,\ RDSE,\ TI)$$

where *RDG* refers to R&D grants enjoyed by the firm from the host government (Yes=1; No=0); *RU* refers to Likert scale rating (1-5) of the presence of research universities; *RDSE* refers to Likert scale rating (1-5) of the presence of strong supply of R&D scientists and engineers; *TI* refers to Likert scale rating (1-5) of the presence of strong training institutions. Regional trade linkages (*RL*) is used as an explanatory variable.

RL were estimated using the following formula:

$$RL = RS/TS + RP/TP$$

Where *RS/TS* refers to percentage share of intermediate sales in total sales to firms in East and Southeast Asia; *RP/TP* percentage share of intermediate purchases in total purchases from East and Southeast Asia.

4.1.3. Instrumental Variable

Foreign ownership was used as an instrumental variable when *RL* was used, while it was used as a control variable when *HI* was regressed.

Human Capital (*HC*) was estimated by taking the percentage share of managers and professionals, and engineers and technicians in the workforce. The choice was possible because of the lack of correlation between *HI* and *HC*.

4.1.4. Control Variables

Foreign ownership (*FO*), size (*S*) and age (*A*) were used as the control variables in the article, and were measured as follows:

FO = 1 if foreign equity in total equity is 50 percent or more.

FO = 0 otherwise.

S = *Ln* (workforce)

A = age of the firm.

All figures used were from year 2011 unless otherwise stated.

4.2. Specification of Simultaneous Equations Models

The two-stage least squares regression model was used to analyse the existence of a statistical relationship between *TC* and *HI*, and between *RL* and *TC* because the dataset used is cross-sectional, and also OLS regressions produced a highly significant constant demonstrating the presence of missing variables. The instrumental variable of *HC* was selected in both regressions as this variable was correlated with *TC,* but not with the explanatory variables of *HI* and *RL*. Hence, the following equations were specified:

$$TC = \alpha + \beta_1 HI + \beta_2 FO + \beta_3 S + \beta_4 A + \mu \qquad (1)$$

$$TC = \alpha + \beta_1 HI + \beta_2 HC + \mu \qquad (2)$$

where *HI* is the explanatory variable, *HC* is the instrumental variable, and *FO, S* and *A* are the control variables.

$$TC = \alpha + \beta_1 RL + \beta_2 S + \beta_3 A + \mu \qquad\qquad (3)$$

$$TC = \alpha + \beta_1 RL + \beta_2 FO + \mu \qquad\qquad (4)$$

where *RL* is the explanatory variable and *S* and A are the control variables. We used *FO* as the instrumental variable in equation 4 because of colinearity problems between *RL* and *HC*.

4.3. Data

A stratified random sampling procedure based on ownership was adopted to gather data from the semiconductor industry in Malaysia. The data collection instrument comes from a refined version of questionnaires used in previous studies by Rasiah (2010). Although data on employment, sales, exports, R&D expenditure and training expenditure were drawn for the years 2000, 2006 and 2011, the analysis is confined to 2011 as the data on most technological, human capital and institutional support proxies were limited to only 2011.

The survey questionnaire was sent to all semiconductor firms in Malaysia. The response rate was 57.5 percent, which was 23 of the population of 40 semiconductor firms in 2012. We managed to obtain responses from all the 10 foreign and 27 supporting firms strongly trade linked regionally but in complementary activities in machinery and equipment and plastic materials (see Table 3). These firms were identified by the 17 foreign and 6 national semiconductor firms that participated in the survey. Hence, the empirical analysis is based on a semiconductor cluster totalling 60 firms.

Table 3. Semiconductor firms by ownership, Malaysia, 2012

	Foreign	National
Sample	*17*	*6*
Population	33	7
Percentage share	51.5%	85.7%
Semiconductor Supporting firms	**10**	**27**
Overall Semiconductor Cluster sample	27	33

Source: Authors survey (2013); Department of Statistics Malaysia (2012).

5. Findings

We analyse technological upgrading in this section. The first sub-section focuses on key firm-level technological indicators, performance and regional trade linkages variables over the period 2000-2011. The second sub-section presents the descriptive statistics. The third sub-section analyses statistical relationships between technological capabilities, and institutional support and regional trade linkages.

5.1. Technological Upgrading and Economic Performance

The semiconductor cluster of firms in Malaysia examined shows significant technological deepening (see Table 4). Although training expenditure in payroll fell from 2.0 percent in 2000 to 1.4 percent in 2011, R&D expenditure in sales (*RDE/S*) and R&D personnel in workforce rose from 3.6 percent and 3.8 percent respectively in 2000 to 7.2 percent in 2011.

Exports in gross output (*X/Y*) rose from 20.0 percent in 2000 to 48.8 percent in 2011. Domestic linkages as measured by sales and purchases in Malaysia in overall sales and purchase rose from 23.2 percent in 2000 to 33.9 percent in 2011. Regional linkages as measured by sales and purchases domestically and to and from all neighbouring countries in East Asia in total sales (100 percent) and purchases (100 percent) rose from 108.2 percent in 2000 to 135.1 percent in 2011.

Table 4: Technology and export structure, semiconductor cluster, Malaysia, 2000-2012

Year	2000	2006	2011
RDE/S (%)	3.6	4.8	7.2
RDP/W (%)	3.8	5.5	7.2
TE/P (%)	2.0	1.8	1.4
X/Y (%)	20.0	36.8	48.8
DL (%)	23.2	24	33.9
RL (%)	108.2	116.0	135.1
N	30	51	60

Note: Of the 60 firms that responded to the survey, only 51 and 30 were around in 2006 and 2000 respectively.
Source: Computed from authors' survey (2013).

5.2. Statistical Results

We present in this section the descriptive statistics involving the dependent and independent variables, and analyse the relationship between technological capabilities (*TC*) and host-site high technology institutional support, and regional trade linkages (*RL*). Whereas the first relationship is obvious, we defined *RL* to influence firm-level *TC* because of the higher technology demands of importing producers in Japan, Korea, Taiwan and Singapore, and to a less extent, purchasers from China and Malaysia.

5.2.1. Descriptive Analysis

The descriptive statistics of the dependent and independent variables are shown in Table 5. The mean and median of the variables *TC* and *RL* are 0.80 and 0.65, and 102.25 and 110.0 respectively. The standard deviation for *TC* and *RL* were 0.50 and 49.9 respectively. The Jarque-Bera statistics show that the distribution for the variables *TC, HI, HC, RL* and *S* are normal (p>0.05). The distribution of the data for the variables *HC* and *S* are not normal.

Table 5: Descriptive statistics, selected variables, semiconductors, Malaysia, 2012

	A	FO	HC	HI	RL	S	TC
Mean	15.85	0.33	56.89	8.00	102.25	5.43	0.80
Median	10.50	0.00	55.00	8.00	110.00	5.33	0.65
Maximum	40.00	1.00	100.00	10.00	200.00	8.99	3.01
Minimum	0.00	0.00	5.00	2.00	0.00	1.95	0.28
Std. Dev.	13.20	0.48	26.88	1.79	49.92	2.13	0.50
Skewness	0.92	0.71	0.17	-1.58	-0.09	0.01	1.45
Kurtosis	2.59	1.50	2.00	2.76	2.28	1.69	2.74
Jarque-Bera	8.95	10.63	2.76	4.00	1.38	4.27	4.51
Probability	0.01	0.00	0.25	0.29	0.50	0.12	0.06
Sum	951.00	20.00	3413.50	480.00	6135.00	325.91	47.78
Sum Sq. Dev.	10285.65	13.33	42640.41	190.00	147021.30	267.51	14.55
Observations	60	60	60	60	60	60	60

Source: Authors survey (2013).

Given the maximum possible score of 16 for *HI,* the mean (8.0) and medians (8.0) are at the medium level and the highest score achieved is 10, while the lowest is 2. The firms in the sample show mean and median ages of 15.9 and 10.5 years respectively with a minimum age of 0.0 years and a maximum age of 40.0 years in 2011. The mean (5.43) and median

(5.33) of the logarithm of employment sizes were close. *HC* had a mean and median of 56.9 and 55.0 respectively with maximum and minimum percentages of 100 and 5 respectively.

5.3. Statistical Relationships

Both equations produced statistically significant results as the F-statistics on model fit was significant for interpretation. There was no multi-colinearity or heteroskedasticity (Cook-Weisberg test) problems among the independent variables. The constants were also insignificant, suggesting that the equations do not have endogeniety problems.

The results show a statistically significant relationship (at 5 percent level) between high technology institutional support (*HI*) and technological capabilities (*TC*), and it is positive (see Table 6). The results show a possibility of the coefficient of *HI* being biased by endogeneity problems. The coefficient of Equation 2 is more reliable because the constant is almost totally insignificant. A one percent improvement in institutional support will raise firm-level technological capabilities by 0.14 percent in the second equation. None of the control variables in equation 1 were significant. The instrumental variable of *HC* was significant and positive in equation 2. *FO* was statistically significant but only at the 10 percent level suggesting that foreign firms do possess a slight advantage in technological capabilities over national firms.

Table 6. Simultaneous equations regression, semiconductors, Malaysia, 2012
Dependent variable: *TC*
Explanatory variable: *HI*
Instrumental variable: *HC*

	Equation 1				*Equation 2*		
	Coeff.	t-stat	p-value		Coeff.	t-stat	p-value
C	0.736	1.15	0.256	*C*	-0.012	-0.012	0.991
HI	0.629	2.037	0.047**	*HI*	0.135	2.181	0.034**
S	0.094	1.576	0.121	*HC*	0.047	1.672	0.100*
A	-0.014	-1.641	0.107				
FO	0.198	1.867	0.073*				
N	60			*N*	60		
R^2	0.228			R^2	0.128		
$\bar{R}^2$	0.150			$\bar{R}^2$	0.095		
F-stat	2.948		0.021**	*F-stat*	3.879		0.027**

Note: * and ** refer to statistical significance at 10% and 5% respectively.
Source: Computed from author's survey (2013).

The relationship between *RL* and *TC* was also significant (see Table 7). The two-stage least squares method shows that *RL* is positively correlated with *TC* at 5 percent significance

level. *FO* was significant at the 10 percent level suggesting that foreign firms do hold a slight technological capability advantage over national firms. However, the influence of *RL* on *TC* is fairly low compared to the influence of host-site high tech institutional support underlining the importance of government policy to stimulate upgrading of firm-level technological capabilities in semiconductor firms.

Table 7. Simultaneous equations regression, semiconductors, Malaysia, 2012
Dependent variable: *TC*
Explanatory variable: *RL*
Instrumental variable: *FO*

	Equation 3				*Equation 4*		
	Coeff.	t-stat	p-value		Coeff.	t-stat	p-value
C	2.134	8.536	0.256	*C*	2.159	-0.012	0.320
RL	0.049	1.807	0.067[*]	*RL*	0.004	2.181	0.027[**]
S	0.097	1.671	0.111	*FO*	0.185	1.769	0.088[*]
A	-0.011	-1.540	0.109				
N	60			*N*	60		
R^2	0.223			R^2	0.112		
$\bar{R}^2$	0.157			$\bar{R}^2$	0.081		
F-stat	3.001		0.025[**]	*F-stat*	3.593		0.034[**]

Note: [*] and [**] refer to statistical significance at 10% and 5% respectively.
Source: Computed from author survey (2013).

Taken together, the relationship between *HI* and *TC* is statistically significant and positive suggesting that institutional support at the host-site in the provision of R&D scientists and engineers, R&D grants and R&D labs and universities have been important in stimulating technological upgrading. *RL* has also been important in driving technological upgrading as it is also positively correlated with *TC*. While *RL* has a positive influence, *HI* is more strongly correlated with *TC*.

6. Conclusions

The electronics industry in general and the semiconductor industry in particular has been a major contributor to the growth of manufacturing exports and employment in Malaysia. Connecting to global value chains, primarily through the transnationalization of production activities, has been the prime source of semiconductor exports from Malaysia. From a mere focus on investment and employment in the early 1970s until the mid-1980s, the government began to target the semiconductor industry for technological upgrading since 1986 but

especially from 1991. R&D grants to support technological upgrading and the unlimited import of R&D scientists and engineers became important particularly since 2005.

The statistical results between host-site institutional support and technological capabilities, and regional trade linkages and technological capabilities were statistically significant and positive suggesting that the provision of R&D grants, and presence of R&D labs and universities, and R&D scientists and engineers (institutional support), and regional trade linkages has helped strengthen firm-level technological capabilities in the semiconductor industry. RL has also been important as it is positively correlated with TC. However, HI is more strongly correlated with TC than RL, demonstrating the greater importance of the former over the latter in explaining upgrading at the host-country of Malaysia. Foreign firms hold a slight technological capability advantage over national firms. The results support a strong role for host-site institutional support as essential to stimulate firm-level technological upgrading. Hence, host-site institutional support has mattered strongly in the level of technological capabilities found in semiconductor firms in Malaysia. Regional trade linkages have been important too but its significance on firm-level technological capabilities has been less important compared to host-site institutional support.

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