The Effect of R&D on High-Tech Product Export Competitiveness: Empirical Evidence from Panel Data of East Asian Economies†

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Abstract

This study investigates the effects of the two most important indicators of a nation's state of scientific infrastructure: R&D investment and the number of R&D researchers engaged in high-tech product export competitiveness for a panel of 11 countries/economies from East Asia from 1994 to 2010. A GMM panel estimation method was employed to account for the dynamic effect of trade and to control for un-observed country specific effects that may arise due to an inter-country differences and intra-country dynamics. Accordingly, the empirical results reveal that (once controlled for the influence of per capita income) physical capital and infrastructure, a 1% increase in a country's expenditure on the ratio of R&D to GDP may increase high-tech product export performance by approximately $397 million per year. Other factors constant, a 1% increase in the number of R&D researchers is expected to increase the ability to export high-tech products by approximately $67 million. The East Asian development experience demonstrates how latecomers can follow systematic industrialization and join the handful of economies that have come a long way toward closing the knowledge gap with the global technological leaders. However, this does not mean that the policy approaches and overall commitments pursued by each East Asian economy in relation to R&D investment and acquisition of an adequate pool of researchers, and their ultimate achievements in high-tech product export competitiveness were uniform. As a result, there is still a significant variation among countries/economies in terms of performance. This study recommended a number of potential tools and policy instruments that may assist policy makers to foster R&D as an engine to enhance the high-tech product export competitiveness.

KEYWORDS: R&D outsourcing, productivity, R&D investment

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1. INTRODUCTION

East Asian economies[1] have achieved a sustained and rapid growth in per capita income and underwent structural economic changes over the last four decades. Although there are considerable differences among East Asian economies, as a group, they have consistently outperformed other developing regions since the 1960s, and their achievement has attracted the universal attention of policy makers. East Asia has become an undisputed development success story and the most dynamic region in the world for the speed of industrialization by being transformed from exporters of primary products to exporters of manufactured products over the last four decades. Accordingly, most successful East Asian economies followed a systematic industrialization path that begins with labor-intensive light industries such as textile manufacturing, followed by capital-intensive heavy industries, and ultimately technology-intensive manufacturing. The East Asian development experience is a good example of how latecomers can develop, as long as they put necessary pre-conditions (such as human capital, financial capital, infrastructure, and R&D investment) in place. Recent studies have also revealed that the exceptional growth of most East Asian countries was attributed to the spectacular productivity growth in comparison to other developing countries (Thomas and Wang, 1997).

Productivity growth characterizes the process of transformation and the move from a traditional to a modern economy. Advancing innovation and technology adoption is a permissive source and a necessary condition for development (Kuznets, 1973). Entrepreneurship and human capital play an important role in this process of productivity growth. Schumpeter points out that entrepreneurship is an important driver of development through a process of creative destruction (Schumpeter 1947). It was stressed in the Schumpeterian literature that prospects for productivity growth differ across activities because of the differences in technological opportunities (Schumpeter 1934, Nelson and Winter 1982). In addition, endogenous growth models highlight the key role of sectors that produce knowledge and their linkages in the economy for productivity growth (Romer 1990, Grossman and Helpman 1991).

To be competitive in the world of technology, research and development (R&D) is widely accepted as the method for technological improvement. R&D benefits firms in cost reduction and product development. R&D reduces production costs through productivity improvement (Crepon, Dugest, and Mairesse, 1998), labor saving (Johnston, 1966), and increasing returns to scale (Romer, 2001), cost reductions (Johnston, 1966; Blind, 2001; Rodriguez and Rodriguez, 2005), and new product development (Krugman, 1979; Grossman and Helpman, 1990). R&D enhances the performance and competitiveness of firms as well as advances the technology frontier that increases the capability of firms to produce new products (or improve existing products). Consequently, new products can allow firms to maintain their profits and competitiveness through the replacement of obsolete products.

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[1]The 15 East Asian economies are Brunei Darussalam, China, Hong Kong-China, Indonesia, Japan, Republic of Korea, Laos, Macao-China, Malaysia, Myanmar, Philippines, Singapore, Taiwan-China, Thailand, and Vietnam.

R&D does not directly generate revenue in the same way that production expenses do, so it can be trimmed with limited short-term impact on revenue. Firms attempt to invest in R&D at a level that maximizes future profits along with maintaining the current market share and increasing operating efficiency. R&D expenditures indicate the level of effort dedicated to the production of future products and process improvements in the business sector; by extension, they may reflect a market demand perception by firms for new and improved technology.

Trade performance in high-tech industries is largely based on the national level of R&D expenditures. High-tech includes all products with high R&D intensity such as computers and office equipment, consumer electronics, semi-conductors, communication services, software (and related services), pharmaceuticals, aerospace industries, and scientific instruments (OECD, 1999). The high-tech product exports variable is intended to measure national competitiveness in the high-tech sector.

According to Seyoum (2004), competitiveness is defined as the national ability to produce and distribute goods in the international economy in competition with those produced in other countries. A good measure of national high-tech competitiveness is the presence of substantial and sustained high-tech product exports. High-tech also provides firms with a competitive advantage by changing the key factors of success. In some cases, small firms with limited experience have managed to overcome the cost handicap created by dominant competitors through technological innovation. In the future, high-tech industries will be the primary source of wealth generation, as opposed to resource, labor, and capital-intensive industries that dominated the 20th century (Reich, 1991). Many countries have now embarked on technology-based development and 'New Silicon Valley's' have begun to develop in many parts of the world (Seyoum, 2004). The United States continues to be the leading producer of high-tech products followed next by Japan. The share of West European nations has been in decline while that of Asia (particularly that of South Korea and Taiwan) has shown dramatic gains (National Science Foundation, 2002). This study underscores the importance of R&D for high-tech export competitiveness in industries and investigates the causal relationship under the context of contemporary East Asia.

1.1. Research Objectives

(a) Develop and econometric model for the nexus of technological infrastructures (R&D intensity; skilled R&D human resources) and high-tech product exports.
(b) Estimate the impact of R&D investment intensity and skilled R&D human resources on high-tech export performances of countries in East Asia, by taking economic, policy, political, and institutional factors into account.

1.2. Research Questions

The research questions derived from the above objectives are:
(a) What exactly are the separate effects of R&D intensity and skilled R&D human resources on the high-tech product export competitiveness?
(b) If R&D can have a positive impact on the high-tech export performance of a country, then what

are the policy options available to support the process?

(c) What are the areas in which each country in East Asia must pay significant attention to and draw lessons from past successes and failures in regards to R&D?

(d) What other factors may increase the divergence in high-tech export performance over time and across countries in East Asia?

1.3. Significance of the Study

(a) Existing studies on the relationship between R&D and high-tech technology exports are mainly focused on advanced countries. Previous studies fill the gap with a focus on East Asian economies and develop a model of the nexus between R&D and the competitiveness of high-tech product exports.

(b) Unlike most empirical studies on export performances that use conventional cross-sectional data without looking at the time effects or a typical time series analysis of a single country without looking at the cross-country effect, this study employs a longitudinal (panel data) to figure out both cross-country and time effects.

2. SELECTION OF EXPLANATORY VARIABLES THAT INFLUENCE HIGH-TECH PRODUCT EXPORTS

2.1. Lagged (past) value of high-tech product export performance

The first variable considered in this study with a significant influence on the current national level of high-tech product export performance (EPHit) is the lagged (past) value of high-tech product export performance (EPHit-1). Trade is path dependent and hence it is logical to assume for countries with significant past exports that businesses have set up distribution and service networks in a partner country that has led to entrance and exit barriers due to sunk costs. In addition, consumers have grown accustomed to the products of partner countries (habit formation). Ignoring this may lead to an incorrect inference (Bun and Klaassen, 2002); therefore, current high-tech product export competitiveness is likely influenced by its past performance in high-tech product exports. The proposition is that lagged high-tech product export performance positively influences the current level of high-tech product export performance.

2.2. R&D Intensity (Ratio of R&D expenditures to GDP)

R&D investment increases the absorptive capacity (i.e., the capacity to absorb knowledge created from relationships formed with agents outside the firm) as well as the capacity to use that knowledge to increase firm performance (Gilsing et al., 2008; De Jong and Freel, 2010). R&D spending can provide countries a competitive advantage and support the transition to a knowledge-based economy; subsequently, several developing countries (mainly East Asian economies) are increasingly exporters of high-tech products mainly driven by significant domestic R&D expenditures as well as a foreign to domestic technological transfer. R&D spending by industry is also closely correlated to the international competitiveness of an industry, this indicates that the pattern of government spending helps shape the prospects of different industries. R&D intensity (defined as R&D spending as a percentage of GDP) measures the relative importance of R&D in the national economy. As an indicator of international economic competitiveness, many countries have a target to invest 1% of their GDP in R&D; in addition, some East Asian countries (such as Japan, South Korea, and Singapore) have set their target at 3% or more. Significant R&D investment is key to ensure long-term development via building knowledge-based societies and indicates that the level of effort dedicated to producing future products and process improvements in the business sector such as specialization in high-tech product exports. It has been proposed that R&D intensity that can be captured by the ratio of R&D expenditures to GDP is expected to have a positive impact on high-tech product export competitiveness via its role to generate new and improved technology.

2.3. Number of R&D researchers

High-tech product competitiveness is inconceivable without the availability of highly skilled scientists and engineers to create and sustain a significant level of innovative activity (Keeble and Wilkinson, 2000). The number of R&D researchers in a given country indicates the R&D potential of the country as well as the available scientific infrastructure of the country. Similarly, the technological infrastructure factor contains two variables of total expenditure on R&D per capita as well as scientists and engineers engaged in R&D. These variables represent the two most important indicators of the state of scientific infrastructure information. For this reason, we propose that the number of R&D researchers may have a direct and significant effect on high-tech product export competitiveness.

2.4. Income per capita

Income per capita measures the level of development of a given country and is expected to have a significant impact on the ability of a country to create a competitive R&D capacity in terms of R&D spending as well as the production of a large pool of researchers. Subsequently, this is expected to have a significant effect on the capacity of a country to specialize in high-tech product exports. The experience of developed and emerging economies demonstrates that the level of development is an important determinant for a country to transition from producing and exporting more labor intensive agricultural and manufacturing products towards the production and export of more knowledge intensive high-tech products. The level of development of a country (measured in terms of GDP/capita) may have a significant and profound effect on the ability of a country to export high-tech products.

2.5. Physical Infrastructure

Cross-country studies by Canning and Bennathan (2000) indicate that infrastructure (particularly telecommunications infrastructure) significantly increases economic growth. In addition, Wheeler and Mody (1992) proves that good infrastructure is a required condition for successful foreign investor operations. Infrastructure is expected to directly influence the export performance of a given country and includes high-tech product exports.

2. 6. Education

The stock of educated labor proxied by the level of secondary school educational attainment is a key for economic growth as well as an intrinsic measure of human development. States that fail to ensure adequate education are less likely to grow. The education variable has a positive and significant long-term effect on the ability of a country to build a large pool of R&D researchers and enhance the technological capability to produce and export high-tech products. This variable has been witnessed in several developed countries, new industrialized countries, and recently in various emerging economies; subsequently, the education variable is assumed to positively affect the ability of a country to develop high-tech product export competitiveness.

2.7. Domestic Capital

Export competitiveness is a function of capital accumulation mainly driven by domestic capital formation, although it is also possible for it to be complemented (but not substituted) by foreign capital. The experience of most industrialized countries that include late comers in East Asia (such as South Korea, Singapore, Taiwan, and Hong Kong) confirms that domestic capital (mainly driven by domestic saving) was essential for their dynamic economic growth in general and high-tech product export competitiveness. In line with this, profit reinvestment was instrumental for the expansion of capital accumulation as well as increased export competitiveness. For this reason, we propose that domestic capital, measured in terms of gross fixed capital formation as a ratio of GDP, may have a positive and significant effect on high-tech product export competitiveness.

2.8. Foreign Direct Investment (FDI)

FDI plays a vital role to provide capital to the host economy, promote technology transfers, modernize management skills, and improve corporate governance that subsequently increase labor productivity, accelerate economic growth (Markusen and Venables, 1999; Blomstrom and Kokko, 1998), and enhance high-tech product export competitiveness. It is proposed that FDI has a positive and significant effect on high-tech product export competitiveness.

3. SCOPE OF THE STUDY, DATA AND DATA SOURCES

This study developed an intensive empirical analysis for a panel of 11 countries/economies in East Asia from 1994 to 2010. We only included countries (China, Hong Kong, Macao, Indonesia, South Korea, Japan, Singapore, Malaysia, Thailand, the Philippines, and Vietnam) with complete data for all factors throughout the years.

The data for R&D intensity and the number of R&D researchers was collected from the United Nations Department of Economic and Social Affairs (UNESCO) Statistical Yearbook;

whereas, the data for high-tech product exports were obtained from the World Development Indicators (WDI) dataset. High-tech product exports include aerospace related products, computers, pharmaceuticals, scientific instruments, and electrical machinery. Additionally, the data for other control variables were collected from the WDI dataset, Central Statistical Offices, and Central Banks of each countries/economies included in the study. Table 1 summarizes the list of explanatory variables, their expected signs, and data sources; in addition, the statistical data analysis was conducted using STATA statistical software.

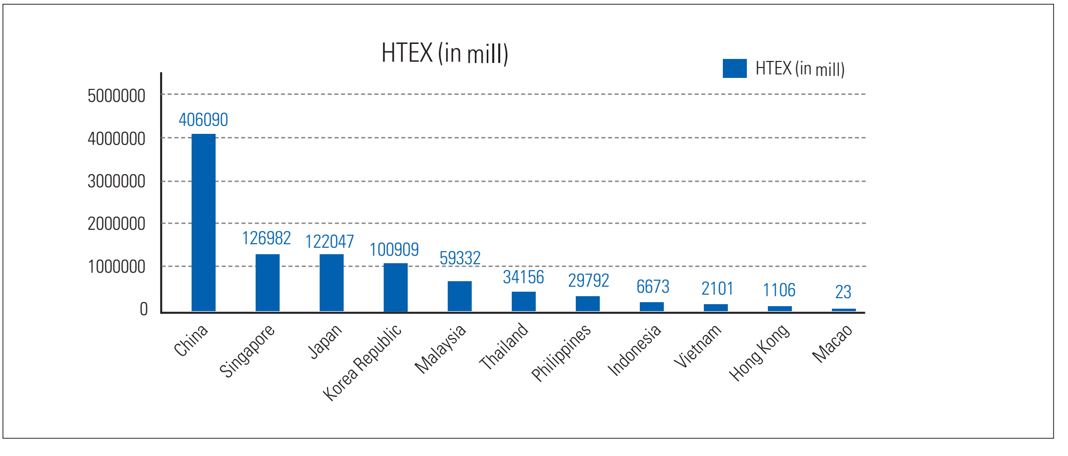
TABLE 1. Independent Variables, their Expected Signs and Data Sources

Variable	Indicator	+/-	Data Sources
R&D Intensity	Ratio of R&D expenditures to GDP	+	UNESCO Statistical Yearbook; WDI
No. of R&D Researchers	Number of R&D Researchers	+	UNESCO Statistical Yearbook; WDI
Level of Development	GDP/Capita (PPP)	+	WDI
Physical Infrastructure	Telephone/100 people	+	WDI Data Base
Education	Secondary School Enrolment Ratio	+	WDI Data base
Domestic Capital	Gross Fixed Capital Formation/GDP	+	WDI Data base
Foreign Capital	Inward FDI	+	WDI Data base

4. COMPARATIVE PERFORMANCE OF EAST ASIAN ECONOMIES RELATED TO HIGH-TECH PRODUCT EXPORTS, R&D INVESTMENT, AND NUMBER OF R&D RESEARCHERS

East Asia has emerged as an important cluster for the manufacture of high-tech products; however, there still seems to be a significant variation among countries/economies in terms of performance related to high-tech product exports. Figure 1 shows the top four countries in East Asia specialized

FIGURE 1: High-tech Product Export Competitiveness for East Asian Economies in 2010



in high-tech product exports in 2010 (China, Singapore, Japan and South Korea) with a value of $406.1 billion, $127 billion, $122 billion, and $100.9, respectively; in addition, countries such as Malaysia, Thailand, and the Philippines followed with high-tech product exports of $59.3 billion, $34.2 billion, and $29.8 billion, respectively.

The high-tech export performance of selected countries is compared with R&D expenditures. Figure 2 shows that Japan, South Korea, Singapore, and China lead with 3.6%, 3.4%, 2.8%, and 1.8% of GDP investments in R&D, respectively. In particular, R&D spending by China has rapidly increased in absolute terms, although recent estimates still show its R&D spending to be smaller relative to GDP; however, countries like Indonesia and the Philippines invest only 0.19% and 0.17% of their GDP in R&D, respectively. This indicates that the more a country invests in R&D, then the more it creates high-tech product export competitiveness.

FIGURE 2: R&D Expenditures (% GDP) of East Asian Economies in 2010

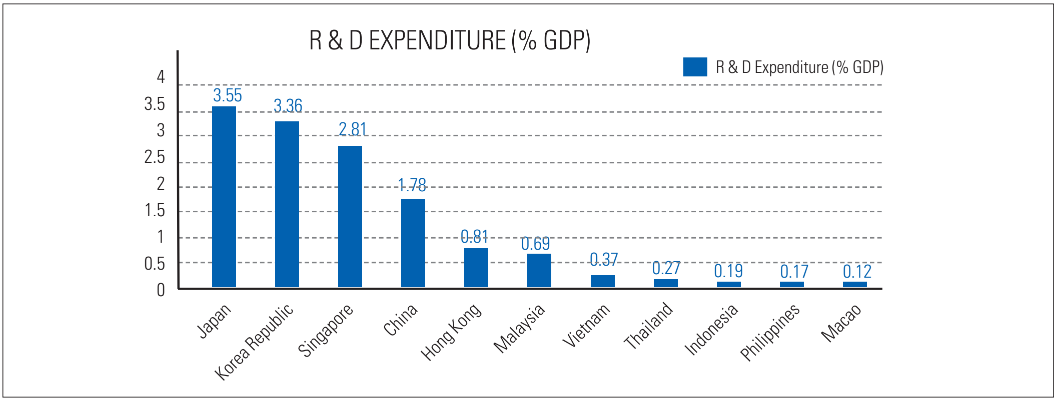
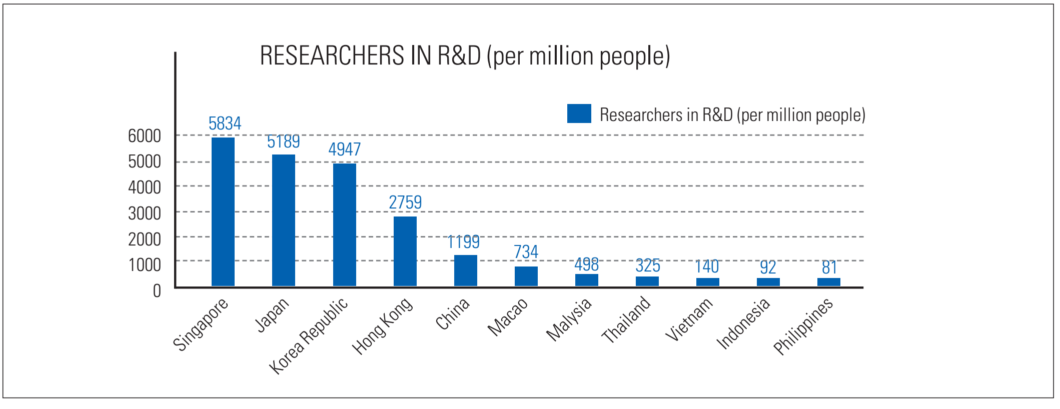


Figure 3 shows the number of R&D researchers per 1 million people in 2010, Singapore (5834), Japan (5189), South Korea (4947), Hong Kong (2759), and China (1199). This indicates that countries/economies with higher numbers of R&D researchers are likely to perform higher in terms of

FIGURE 3: Number of R&D Researchers (per million people) in East Asian economies in 2010



exporting high-tech products compared to countries with lower number of R&D researchers. Figure 3 also shows the wide variation among East Asian economies in terms of their pool of researchers. For instance, Singapore had 5834 researchers per million people in 2010 while the Philippines, Indonesia, and Vietnam had only 81 researchers, 92 researchers, and 140 researchers per 1 million people, respectively.

5. RESEARCH METHODOLOGY AND MODEL SPECIFICATIONS

This study applies a dynamic GMM model to address the dynamic nature of trade. A System-GMM estimator developed for dynamic panel data estimation (Blundell and Bond, 1998; Arellano and Bover, 1995) is the most appropriate estimation method to control for country-specific effects through the inclusion of a lagged dependent variable. For countries that traded a lot in the past, businesses have developed distribution and service networks in partner countries that have led to entrance and exit barriers due to sunk costs; in addition, consumers have grown accustomed to the products of partner countries (habit formation) and ignoring this situation may lead to an incorrect inference (Bun and Klaassen, 2002). It is likely that the current bilateral trade between those countries is also high (Eichengreen and Irwin, 1997).

Lagged trade positively affects current trade; in addition, there are various reasons to include lags. The inclusion of lags accounts for a partial adjustment of behavior over time. Individuals might partially adjust their behavior over time (for example to reach a long-term equilibrium). Another motivation for that includes lags would be to account for particular factors that include exogenous shocks that have a continual effect over time. The coefficients in lagged dependent variables indicate whether these factors have a greater impact over time or whether their impact gradually decays (Wawro, 2002).

Unobserved heterogeneity is the main problem of factual research, panel data estimation techniques allow us to deal with inter-country differences and intra-country dynamics that allow the control of missing or omitted variables; in addition, panel data provides more informative data, more variability, less collinearity among variables, more degrees of freedom, and increased efficiency (Gujarati, 2003). For dynamic panels with lagged dependent variables, Arellano and Bond (1991) and Arellano and Bover (1995) have used general methods of moments (GMM), which are asymptotically normal (Wooldridge, 2002). The GMM approach is appropriate to deal with lagged dependent variables as well as account for the potential endogeneity of regressors as well as heterogeneity across countries. In this study, the GMM panel estimator is expected to extract consistent and efficient estimates of the impact of R&D intensity and skilled R&D human resources for high-tech export competitiveness. By accounting for un-observed country-specific effects and allowing for the inclusion of lagged dependent variables as regressors, and controls for endogeneity in all explanatory variables that ultimately reduce bias. Tests will be conducted using a panel data of 11 Asian economies from 1994 to 2010; the following model examines the effects of R&D intensity and skilled R&D human resources for high-tech product export competitiveness.

(1) $EHP_{it} = \beta_0 + \beta_1 EHP_{it-1} + \beta_2 RDE_{it} + \beta_3 SLFR_{it} + \beta_3 Z_{it} + a_{it} + \delta_t + e_{it}$

Where EHP_{it} captures high-tech product export competitiveness in value terms (USD) of country i in year t, EHP_{it-1} is the lagged value of high-tech product export competitiveness, RDE_{it} and $SLFD_{it}$ stand for R&D intensity (the ratio of R&D expenditures to real GDP) and skilled R&D human resources (number of R&D researchers), respectively. As well, Z_{it} refers to a set of control variables that include: FDI inflow, domestic capital formation, human capital (education & health), and physical infrastructure as well as other macroeconomic variables such as exchange rate policy, and inflation, ai captures unobserved and time invariant country effects, δ_t represents time effects, and e_{it} captures the residual errors in measurement.

Due to the presence of a lagged dependent variable (EPH_{it-1}), neither the OLS estimator nor the Fixed Effect (FE) estimators are un-biased and inconsistent for the estimation of our model. Consistent and efficient estimates of capital formation equation can be obtained using the generalized method of moments (GMM) IV estimator of Arellano and Bond (1991) estimation technique; however, we first have to perform a first difference (FD) transformation of Equation 1 in order to remove a potential correlation between a_i, EPH_{it-1}, X_{it}, and Z_{it} as follows:

(2) $(EHP_{it} - EHP_{it-1}) = \beta_0 + \beta_1 (EHP_{it-1} - EHP_{it-2}) + \beta_2 (RDE_{it} - RDE_{it-1}) + \beta_3 (SLFR_{it} - SLFR_{it-1}) + (Z_{it} - Z_{it-1}) + (\delta_t - \delta_{t-1}) + (e_{it} - e_{it-1})$

(3) $\Delta EHP_{it} = \beta_0 + \beta_1 \Delta EHP_{it-1} + \beta_2 \Delta RDE_{it} + \beta_3 SLFR_{it} + \beta_4 \Delta Z_{it} + \Delta\delta_t + \Delta e_{it}$

The fixed country-specific effect can be removed through the transformation of the regressors through differencing since it is consistent; therefore, $\Delta a_{it} = (a_{it} - a_{it-1})$ becomes zero. It is then possible to investigate the specific types of economic freedoms essential for capital formation.

6. CORRELATION ANALYSIS

Table 2 confirms that R&D intensity as measured by the ratio of R&D expenditures to GDP is directly and significantly correlated with the current high-tech product export competitiveness of a country. Similarly, the variable that shows skilled R&D human resources (as measured by the number of R&D researchers) is positively correlated with the current high-tech product export competitiveness of a country. The level of development of a country as measured by GDP/Capita (PPP) is positively and highly correlated with the ability of a country to produce and export high-tech products. In addition, the physical infrastructure of a country shown by the number of telephones per 100 people and human capital (especially investment in education) are found to be important variables that are positively and significantly correlated with high-tech product export competitiveness. Table 2 confirms a gross fixed capital formation that shows the ability of a country for domestic capital accumulation and foreign direct investment (FDI) inflow that are positively correlated with the high-tech product export competitiveness of Asian countries.

TABLE 2. Partial Correlation of EHP with the Independent Variables

Variable	Correlation	Significance
(EHP)it-1	.465	0.000***
R&D Intensity (ratio of R&D expenditures to GDP)	.2443	0.001***
Number of R&D Researchers	.1402	0.060*
GDP/Capita (PPP)	.3038	0.000***
Physical Infrastructure (telephone/100 people)	.3468	0.000***
Education (secondary school enrolment ratio)	.1573	0.035**
Fixed Capital Formation/GDP (Domestic Capital)	.2310	0.107*
Inward FDI (Foreign Capital)	.5988	0.000***

Correlation shows only the degree of association not causation. Subsequently, it is imp ortant to examine the effect of R&D intensity as measured by the ratio of R&D expenditures to GDP and skilled R&D human resources as measured by the number of R&D researchers (as well as other important control variables) for high-tech product export competitiveness using the GMM model selected for this study.

7. REGRESSION RESULTS

The effect of R&D intensity and skilled R&D human resources on high-tech product export competitiveness is estimated and shown in Table 3. The GMM-1 column refers to the benchmark regression estimation with the following explanatory variables: the lagged (past) value of high-tech product export competitiveness (EPH_{it-1}), R&D Intensity as measured in the ratio of R&D expenditures to GDP, Skilled R&D Human Resources as measured by the number of R&D researchers, and the GDP/Capita in purchasing power parity.

8. DISCUSSION OF THE RESULTS

The regression estimates (GMM-1, GMM-2, GMM-3, and GMM-4) displayed in Table 3 shows that the coefficient on the lagged dependent variable is positive and statistically significant at the 1% level. This suggests strong path dependence for high-tech product exports for countries with previous and significant high-tech product exports that may have already set up distribution and service networks in a partner country that has created entrance and exit barriers due to sunk costs. In addition, consumers may have grown accustomed to the products of partner countries (habit formation); subsequently, it is likely that high-tech product export performance is also high. For instance, the coefficient of the lagged variable for high-tech product exports (EHP_{it-1}) estimated using GMM-4 (the full-fledged model) is about 0.313 and indicates that a 1% increase in past high-tech product export performance may increase current high-tech product exports by about $313 million.

TABLE 3. Dependent Variable: High-Tech Product Export Competitiveness (USD billion)

Explanatory Variables	GMM-1	GMM-2	GMM-3	GMM-4
$(EHP)_{it-1}$	.402*** (.073)	.316*** (.064)	.314*** (.064)	.313*** (.064)
R&D Intensity (Ratio of R&D expenditures to GDP)	.296*** (.127)	.323** (.165)	.351*** (.149)	.397*** (.172)
Skilled R&D Human Resources (No. of R&D Researchers)	.065*** (.025)	.073*** (.022)	.070*** (.022)	.067*** (.021)
GDP/Capita (PPP)	.038*** (.004)	.032*** (.004)	.031*** (.004)	.032*** (.004)
Gross Fixed Capital Formation/GDP (Domestic Capital)		.114*** (.041)	.108*** (.041)	.109*** (.041)
Inward FDI (Foreign Capital)		.403*** (.067)	.397*** (.068)	.412*** (.069)
Physical Infrastructure (Telephone/100 People)			.271** (.136)	.295** (.173)
Education (secondary school enrolment ratio)				.332* (.191)
Constant	-24.615 (3.559)	-25.399 (4.339)	-34.624 (3.718)	-12.929 (6.128)
No. of observation	165	165	165	165
No. of groups	11	11	11	11
Obs. Per group	15	15	15	15
Wald Chi2 (8)	2976.72	4126.67	4098.58	4164.19
Prob>chi2	0.0000	0.0000	0.0000	0.0000

Notes: [a] *GMM-1 refers to the benchmark regression estimation that used the following explanatory variables: the past year value of high-tech product export competitiveness (EPH_{it-1}), R&D Intensity as measured in the ratio of R&D expenditures to GDP, No. of R&D Researchers as measured by the number of R&D researchers, and the GDP/Capita in purchasing power parity.*
[b] *Figures in parentheses indicate standard error.*
[c] **, ** and *** indicate level of significance at 10%, 5% and 1%, respectively.*

Using all four alternative models as shown in Table 3, R&D Intensity (measured in terms of the Ratio of R&D expenditures to GDP) is found to be a statistically significant determinant for high-tech product export competitiveness. This has become more evident from the results of GMM-4 of Table 3 where the R&D coefficient is 0.397 implies a 1% increase in national expenditures and the ratio of R&D expenditures to GDP may increase high-tech product export performance by $397 million per year. This shows why countries such as Japan, South Korea, Singapore, and China (that are the top per capita R&D spending countries) are simultaneously the East Asian top-performers in high-tech product exports. The ability of a country to export high-tech products is significantly influenced by its capacity to invest a significant portion of its GDP in R&D. Successful East Asian economies have managed to build independent national innovation systems through a reliance on public R&D expenditures versus private R&D expenditures in the early stages of industrial development where significant public R&D expenditures supported innovation capacity in general and high-tech product export competitiveness in particular.

Skilled R&D human resources (as measured in terms of the number of R&D researchers) is the next important variable factor for the ability of a country to specialize in high-tech product exports is said to be the level of . The number of R&D researchers indicates the R&D potential in a country. Accordingly, the regression results from Table 3 of GMM-1, GMM-2, GMM-3, and GMM-4 indicate that skilled R&D human resources was a statistically significant factor at the 1% level and showed its relevance to induce the ability of a country to specialize in high-tech product exports. For instance, the result from the GMM-4 of Table 3 shows that a 1% R&D researcher increase raises the ability of a country to export high-tech products by approximately $67 million. A country with a high number of R&D researchers will be more likely specialized in high-tech product exports. This is shown by the experience of Singapore, Japan, South Korea, Hong Kong, and China (the top 6 economies in East Asia in terms of accumulating the highest number of researchers per 1 million people) that are simultaneously the top economies in high-tech product exports. However, countries/economies with a relatively low level of researchers per 1 million people in East Asia such as Vietnam, Indonesia, and the Philippines have lower high-tech product export performance.

The regression results of Table 3 shows that the level of development (as indicated by the national GDP/capita) matters for the ability of a country to specialize in high-tech products. The result from GMM-1, GMM-2, GMM-3, and GMM-4 confirm that one of the major factors in variation for high-tech product export performance among East Asian economies was due to the variation in the level of development as measured by GDP/capita. The results of GMM-4 (the main model) in Table 3 show that if a country increases its GDP/capita by 1%, the export performance of that country may increase approximately $32 million per year. Countries such as Singapore, Japan, South Korea, and recently China have performed well in increasing their income per capita level over the last three/four decades; subsequently, they are very successful high-tech product export countries compared to other countries in the region with a relatively low per capita income.

Capital formation is vital for a country to stimulate high-tech product exports and this study attempted to analyze the effects of domestic capital (as measured in terms of gross fixed capital formation as a percentage of GDP) and foreign capital (as measured in terms of FDI inflow). These two variables were included in the GMM-2, GMM-3, and GMM-4 models of Table 3 and the results reveal that domestic capital and foreign capital play significant roles in East Asian economies as an economic hub for high-tech product exports. The results of GMM-4 of Table 3 demonstrates that a 1% increase in domestic capital formation and FDI inflow can boost high-tech product exports by $109 million and $412 million, respectively. These results are consistent with the general reality that East Asian economies (especially those of Japan, South Korea, Singapore, Hong Kong, Taiwan and recently China as well as to some extent Malaysia and Thailand) were able to catch-up with the industrialized economies. This was based on their ability to accumulate capital driven by domestic savings and foreign direct investment that created a conducive macroeconomic and political investment environment. This is also an indicative of how important FDI is for a host economy for the sake of capital flow as well as for an important technological transfer to the host economy. Domestic and foreign capital formations are imperative to stimulate the economy towards high-tech products.

Infrastructure (particularly telecommunications infrastructure) significantly increases the ability of a country to specialize in high-tech product exports. For instance, the statistical result from the GMM-4 of Table 3 show that a 1% increases in telephone networks per 100 people may create a conducive atmosphere to raise high-tech product exports approximately by $295 million per year. Last, the education variable proxied by the secondary school enrolment ratio of each country has been statistically significant at the 5% level in the GMM-4 Model. The GMM-4 results imply that a 1% increase in the secondary school enrolment ratio may have a long-term effect to increase high-tech product export competitiveness by $332 million and confirms education as the driving force of development in general and high-tech product export competitiveness in particular.

9. CONCLUSIONS AND POLICY IMPLICATIONS

Innovation is widely regarded as the central process for economic growth and the competitiveness of nations. East Asia is an important cluster for the manufacture of high-tech products over the past three/four decades; subsequently, governments in East Asian economies (such as Japan, Korea, Taiwan, China, Korea, and recently China) were active to follow a strong interventionist and nationalist route to build R&D capacity. These countries have become economies that have narrowed the knowledge gap with global technology leaders. Nobel laureate, Kenneth Arrow (1962) noted that, "R and D cannot be left entirely to the private sector". The primary economic rationale for a government R&D role is that the private market would not adequately address basic or fundamental research since the full economic value of a scientific advance is unlikely to accrue to its discoverer, especially if the new knowledge can be replicated or disseminated at low cost (Bernanke, 2011). Government has a role to encourage basic science investments that may not have immediate commercial applications and foster new technology investments where the risks may be too great for a single firm. Government should actively design well-structured technology policies, technical education programs, the spread of best practice, encourage scientific excellence, establish a proper regulatory environment, and define technical standards.

The lesson that we draw from this study is that the innovative capacity of a country is the basic driving force behind its economic performance and the ability to develop a high-tech export competitiveness. As Freeman (1994) noted, it is a technological innovation capability that forms a major source of competitive advantage. However, it should be noted that the establishment of a strong scientific infrastructure cannot be realized overnight and it takes a long time for a country to reach a technological frontier where innovation becomes the principle driver. The experience of East Asian economies successes suggests that firms should imitate high performing resources or develop alternative resources that could produce similar benefits in order to sustain competitive advantage (Dierickx and Cool, 1989). For this reason, Adler and Shenbar (1990) have defined a technological innovation capability that consists of four aspects. They are: (i) the capacity to develop new products that satisfy market needs (ii) the capacity to apply appropriate process technologies to produce new products (iii) the capacity to develop and adopt new product and process technologies to satisfy future needs (iv) the capacity to respond to accidental technology activities and unexpected opportunities created by competitors. Successful East Asian economies (first Japan, and then the first generation of newly industrialized economies (NIEs) that include Korea, Singapore, Hong Kong, and Taiwan and very recently China and to some extent Thailand and Malaysia) have managed to build an R&D capacity through innovation and imitation. They have transformed R&D results into products that can meet market needs, design requirements, and production economics. It was because of these integrated efforts that useful economies are increasingly creating a strong competitive advantage in the production of high-tech product exports over the last three/four decades. There is also strong evidence that developing countries are increasingly becoming high-tech product exporters.

Policy approaches and overall commitments pursued by East Asian economies differed in relation to R&D investment and incubating an adequate pool of researchers; subsequently, there is a significant variation among countries/economies in terms of performance. Japan, South Korea, Singapore, and China have invested about 3.6%, 3.4%, 2.8%, and 1.8% of their GDP in R&D, respectively; however, countries like Indonesia and Philippines are committed to invest only 0.19% and 0.17% of their GDP on R&D, respectively. R&D researchers per 1 million people in 2010 were found to be 5834 in Singapore, 5189 in Japan, 4947 in South Korea; however, the Philippines, Indonesia, and Vietnam had only 81 researchers, 92 researchers, and 140 researchers per 1 million people, respectively. Countries with less R&D intensity and inadequate R&D human resources have not succeeded in the diversification of high-tech product exports.

If the government decides to foster R&D as an engine to enhance high-tech product export competitiveness, what policy instruments should it use? A number of potential tools exist that include the direct funding of government research facilities, grants to university or private-sector researchers, contracts for specific projects, and tax incentives. In line with building the R&D capacity of a country, human capital through education, financial capital, and infrastructure through domestic capital and FDI are important to develop strong high-tech product export competitiveness in East Asian economies.

The findings have wide implications for East Asian economies that have the potential to produce a high level of skilled R&D human resources that can contribute to high-tech product export competitiveness. The development models pursued by Japan, South Korea, Singapore, Taiwan, Hong Kong, and recently China set a positive example for other East Asian countries. If governments are committed to a scientific infrastructure and R&D institutions, then countries can learn how an economy can be transformed from the production of labor intensive agricultural and manufacturing products towards the production of more knowledge-intensive high-tech product exports.

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