TOTAL FACTOR PRODUCTIVITY, TECHNOLOGY TRANSFER AND ABSORPTIVE CAPACITY IN DEVELOPING ASIAN COUNTRIES

By

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ABSTRACT

Technological progress or total factor productivity (TFP) is the main factor in sustaining economic growth in the long run. As technological follower, technology transfer is the main source of technology progress in developing Asian countries. Effectiveness of technology transfer requires adequate human capabilities to absorb and adapt foreign technological knowledge. This study attempts to study the relative contribution of TFP growth to economic growth and technological absorption of human capital in the technology transfer process by looking into gender aspect at different levels of education. Solow neoclassical growth accounting method is applied to investigate the contribution of TFP growth to economic growth. The logistic technology diffusion model is used to determine the impact of human capital gender on TFP growth through dual dimensions – innovation and technology transfer for a sample of 12 developing Asian countries over the period of 1970 -2009 by using panel data pooled Ordinary Least Square (OLS), fixed/ random effects model. The growth accounting estimation supports the assimilation views that TFP growth has significantly contributed to the output growth of developing Asian countries. The empirical results indicated that the aggregate of female and male educations is significant in the technology transfer process. In terms of gender disaggregate educational levels, female and male tertiary education showed higher absorptive capacity in facilitating technology transfer. The results also showed that autonomous technology transfer has significant impact on TFP growth. This study shows the absorptive capacity of female and higher education in the technology transfer in enhancing the growth of productivity. As such, several policies may be implemented to enhance the effectiveness of technology transfer process by augmenting tertiary education, reducing the gender education disparity, enhancing the rate of female participation in labour force. Sustaining the economic growth which is based on productivity is important at accelerating the economic development of Asian developing countries.

Keywords: total factor productivity, human capital, technology transfer, absorptive capacity

ABSTRAK

Kemajuan teknologi atau produktiviti faktor keseluruhan (*TFP*) merupakan faktor utama dalam mengekalkan pertumbuhan ekonomi dalam jangka masa panjang. Sebagai pengikut teknologi, pemindahan teknologi ialah punca utama kemajuan teknologi di negara Asia yang sedang membangun. Keberkesanan pemindahan teknologi memerlukan tahap keupayaan sumber manusia tertentu untuk menyerap dan menggunakan pengetahuan teknologi asing. Kajian ini bertujuan untuk mengkaji sumbangan relatif pertumbuhan *TFP* kepada pertumbuhan ekonomi dan kapasiti penyerapan teknologi modal insan dalam proses pemindahan teknologi dengan meninjau daripada aspek jantina di peringkat pendidikan yang berlainan. Kaedah perakaunan pertumbuhan Solow Neoklasikal digunakan untuk menyiasat sumbangan pertumbuhan *TFP* kepada pertumbuhan ekonomi. Model penyebaran teknologi logistik digunakan untuk menentukan kesan jantina insan terhadap pertumbuhan *TFP* melalui dual dimensi - inovasi dan pemindahan teknologi bagi sampel 12 negara Asia sedang membangun untuk tempoh 1970–2009 dengan menggunakan data panel *OLS* dikumpulkan, model kesan tetap/ rawak. Anggaran perakaunan pertumbuhan menyokong pandangan asimilasi bahawa pertumbuhan *TFP* telah memberikan sumbangan yang besar kepada pertumbuhan pengeluaran di negara-negara Asai sedang membangun. Daripada segi penyerapan teknologi, hasil kajian menunjukkan bahawa agregat pendidikan wanita dan lelaki agregat adalah penting dalam proses pemindahan teknologi. Tahap pendidikan daripada segi jantina dipecahkan yang menunjukkan bahawa wanita dan lelaki berkelulusan pengajian tinggi mempunayai tahap kapasiti penyerapan teknologi yang lebih tinggi dalam memudahkan pemindahan teknologi. Hasil kajian juga menunjukkan bahawa pemindahan teknologi autonomi mempunyai kesan yang besar ke atas pertumbuhan *TFP*. Berdasarkan hasil kajian ini, ia menunjukkan bahawa pendidikan wanita dan tahap pengajian tinggi adalah kapasiti penyerapan pemindahan teknologi yang penting dalam meningkatkan pertumbuhan produktiviti. Justeru itu, beberapa polisi boleh dilaksanakan untuk meningkatkan keberkesanan proses pemindahan teknologi melalui peningkatan pendidikan tertiari, mengurangkan perbezaan jurang pendidikan jantina, meningkatkan kadar penyertaan buruh wanita. Mengekalkan pertumbuhan ekonomi berasaskan produktiviti adalah juga penting dalam memacu pertumbuhan ekonomi negara Asia yang sedang membangun.

Kata Kunci: produktiviti faktor keseluruhan, modal insan, pemindahan teknologi, kapasiti penyerapan

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TFP	Total Factor Productivity
FDI	Foreign Direct Investment
NIEs	Newly Industrialised Economies
ASEAN	Association of Southeast Asian Nations
GDP	Gross Domestic Product
ADB	Asian Development Bank
APO	Asian Productivity Organisation
ICT	Information and Communication Technology
UNESCO	United Nations Educational, Scientific and Cultural Organization
R&D	Research and Development
OLS	Ordinary Least Square
FEM	Fixed Effects Model
REM	Random Effects Model
LSDV	Least Square Dummy Variable
VIF	Variance Inflation Factor
PWT	Penn World Table
UNCTAD	United Nation Conference on Trade and Development
IIASA	International Institute for Applies Systems
VID	Vienna Institute of Demography

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

One of the overriding objectives of a nation is to achieve sustained economic growth because it enables the nation to enjoy greater economic prosperity over time which, in turn, elevates the standard of living of its population. If this is the case, then what does it take to attain sustained economic growth? In the past, nations have competed with each other primarily through the political means (i.e. through the colonial power). In the modern world, however, nations choose to compete with each other mainly through the economic means (i.e. through growth-oriented policy). Smith (1776) once posed the question "what determines long-term economic growth rate and hence the prosperity of nations?" Since then, the search for the fundamental determinants of growth has become a continuing research theme.

Basically, a country's economy grows with the combination of factors of production such as capital, labour, land and natural resources. However, economic growth is not just determined by factor accumulation alone, but also by total factor productivity (TFP) which represents the relative efficiency of a country to produce goods and services. TFP is commonly referred so as a measure for technological progress. It incorporates the impact of technological change and other factors that rise further than the quantified contribution of factor accumulation (Solow, 1957).

TFP growth is crucial for sustaining an economy's long-run growth. A country could not sustain its growth by relying on factor accumulation alone because it is subject to diminishing marginal returns. The law of diminishing marginal returns assumption in the neoclassical model implies that as an economy has increasingly accumulated more capital, its per capita growth rate will eventually reduce to zero. Since TFP growth can offset diminishing marginal returns, thus, the relative importance of TFP increases to sustain growth of a country.

There are two sources of TFP growth: domestic innovation and technological transfer. Domestic innovation leads the technological frontier of a country move outward whereas technological transfer causes a country's technology level catch-up to the technological frontier. Domestic innovation refers to the creative use of stock of knowledge to create and develop new applications while technology transfer refers to a process of dissemination of technological knowledge from the innovators to the recipients (Khurana, 2013). Technology is transferred across countries through international economic activities such as international trade or imported capital goods and technological inputs, foreign direct investment (FDI) and skilled diaspora which have been recognised as effective conduits of technology transfer by recent studies (Borensztein et al., 1998; Xu, 2000; Mayer, 2001; Keller, 2004; World Bank, 2008). FDI may involve direct and indirect technology transfer in terms of technological and managerial knowledge, and imported technology is embodied in the imported capital goods. Huge FDI and foreign trade expose economies to new technological knowledge (World Bank, 2008).

What factors that determine the extent of adoption of foreign technological knowledge of lagging countries are a critical issue in the literature of international technology diffusion (Lee, 2001; Keller, 2004). Technology diffusion models relate TFP growth to the relative technology gap between lagging countries and the technology frontier, and the ability of lagging countries to catch-up. Gerschenkron

(1962) argued that technologically backward countries may likely grow faster than the technologically leading countries because they have access to a larger technology stock. This insight indicates that those countries that are farther away from the technological frontier may gain more benefits from investment in technological knowledge than technologically leading countries. Thus, through technology transfer, developing countries may leapfrog at the beginning phase of technological development by gaining greater economies of scale (Gerschenkron, 1962).

So far, most of the innovation and development of new technology activities are largely focused in a relatively few industrial countries such as European countries, Japan and North America. As shown in Figure 1.1, the involvement of developing countries in related research and development (R&D) activities is very low (Coe *et al.*, 1997; Crispolti & Marconi, 2005). In this regard, Keller (2004) found that foreign sources of technology are the main contributors of productivity growth in developing countries; i.e. they contribute at more than ninety percent to productivity growth. Coe *et al.* (1997) also showed that international technology transfer of R&D from industrial countries is significant in influencing the TFP growth of developing countries'. Thus, of the two sources, technology transfer is the main source that induces the technology progress for developing countries and it is a promising mean in the development of a country (World Bank, 2008) and for developing countries to close the technology gap. Therefore, the mean of world technological progress is mainly dominated by technology transfer across countries (Keller, 2004).

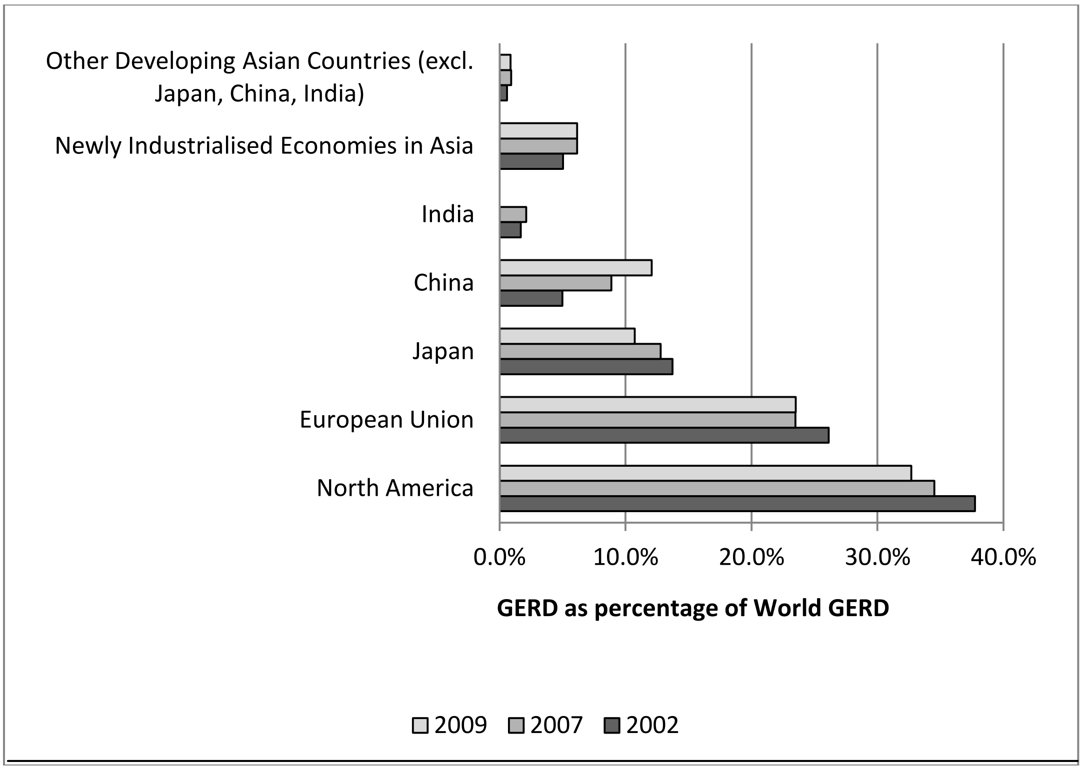

Figure 1.1
Regional Total R&D Expenditure (GERD) as Percentage of World R&D Expenditure, 2002, 2007 and 2009
Sources: UNESCO Institute for Statistics (UIS) estimations, October 2011.

However, technology transfer is not an easy and automatic process; it requires absorptive capacity i.e. adequate ability and capabilities by the lagging countries to adapt and absorb the foreign technological innovations. According to Narula (2004, p.4), "absorptive capacity includes the ability to search and select the most appropriate technology to be assimilated and also activities associated with creating new knowledge." It represents the effectiveness of absorption and internalization of foreign technological knowledge and adapts it in domestic application (Narula & Marin, 2003). In other words, absorptive capacity reflects the competency level of a country in the technology transfer process that determines the extent of absorption and adaptation. This means that the process of effective technological transfer by a technologically backward country is subject to its absorptive capacity. According to the World Bank (2008), the main challenge faced by developing countries is not their accessibility to foreign technologies but their absorptive capacity [1]. This implies that effective technology transfer might be hindered by the low absorptive capacity of a country. Therefore, developing the absorptive capacity of a country is an important mean for increasing productivity growth.

What does it take to develop a country's absorptive capacity? According to Lee (2001) and the World Bank (2008), one of the main reasons why many developing countries fail to exploit the foreign technology innovation is the lack of sufficient human capacity to exploit foreign advanced technologies. This means that effective technology transfer requires adequate human capabilities to apply new technologies from abroad. Human capital represents the ability and efficiency of people to assimilate and accumulate knowledge and apply it in the production process effectively. Therefore, human capital level is a major factor in facilitating technology transfer process and enhancing productivity growth (Eaton & Kortum, 1996; Caselli & Coleman, 2001). The extent of the adaptation and application of foreign technological knowledge depends significantly on the educational attainment of the population due to two important reasons: 1) high skills facilitate people to utilise new knowledge or production technique more efficiently; and 2) higher human capital level increase the likelihood in learning new innovations from abroad beyond the scope of the local society (World Bank, 2008).

[1] Technological absorptive capacity is multi-faceted as mentioned by World Bank (2008) that the speed of technology transfer depends on four main factors: 1) governance and business climates, 2) basic technological literacy, 3) finance of innovative firms and 4) pro-active policies.

Nonetheless, Vandenbussche *et al.* (2006) argued that workers with tertiary education (skilled workers) do not facilitate the technology transfer process for countries which are relatively farther away from the technological frontier[2]. In Vandenbussche *et al.* (2006) model, different types of human capital have vary impact on productivity growth subject to the developmental stage of a country. Their theoretical viewpoint was based on the assumption that unskilled workers (primary and secondary education) facilitate technology imitation or transfer as it is not a skill-demanding activity. These assumptions seem to suggest that developing countries depend on unskilled workers to imitate or adopt foreign technology to catch-up with the technological frontier rather than skilled workers, indicating that developing countries should invest more in lower education rather than higher education.

On the other hand, Mansfield *et al.* (1981) and Benhabib and Spiegel (2005) argued that technology transfer are skill-demanding activities especially for those high-technology products which are performed better by skilled and educated workforce than unskilled workforce; and the return to skilled workers in imitation or adoption activities is higher than innovation activities for countries farther away from the technological frontier (Hanushek & Woessmann, 2011). Such arguments are contrary with Vandenbussche *et al.* (2006) theoretical model prediction assumptions. Applying Vandenbuscche *et al.* (2006) theoretical model, Ang et al. (2011) findings was contrary to Vandenbuscche *et al.* (2006) assumptions regarding the role of unskilled workers on technology imitation for countries farther away from

[2] The theoretical model developed by Vandenbussche *et al.* (2006) assumed that "a marginal increase in the stock of skilled human capital enhances productivity growth all the more the economy is closer to the world technological frontier. Correspondingly, a marginal increase in the stock of unskilled human capital enhances productivity growth all the more the economy is further away from the technological frontier".

technology frontier. They found no productivity growth enhancing effects of unskilled human capital for low income countries. Thus, it could be argued that skilled and educated human capital (tertiary education) facilitates technology transfer more efficiently than unskilled workers.

Indeed, a huge investment in education is needed to produce well-educated workforce. Investment in education is important to increase the quality of employment opportunities and enhance productivity growth of a country. Education delivers skills demanded by the labour market and it is resulting in higher wages. Psacharopoulos (1994) and Psacharopoulos and Patrinos (2004) found that middle-income and low-income countries have the highest returns of education and the returns to schooling for Asia are roughly the same as the world average and further returns to female educational investment are higher than returns to male educational investment.

Increasing investment in human capital and narrowing in the gender disparity has increased female participation rate in the labour force in which well-educated female workforce can enhances female productivity in the economy (Knowles *et al.*, 2002). Psacharopoulos and Patrinos (2004) found that the rate of return in female education is larger than that of the male as shown in Table 1.1. Specifically, the rate of return to education of gender varies by different education levels. Female primary education has lower rate of return than male primary education. At secondary education level, the rate of return of female was higher than male. While, tertiary education for female and male has almost the same rate of return. Schultz (1993) also showed that the female human capital has higher social returns than male human capital. In fact, increasing female education provided social and economic gains by increasing female participation rate and productivity in the labour force (Mammen & Paxson, 2000), reducing fertility and infant mortality, increasing quality of children education and health (Schultz, 1998) and improving the absorption of technology (World Bank, 2008). With the gains considered, there is a need to emphasise the role of female specific education level on productivity growth impact through influencing the extent of the effectiveness in the adoption of technology (e.g. ICT).

Table 1.1
Returns to Education by Gender

Educational Level	**Male**	**Female**
Primary	20.1	12.8
Secondary	13.8	18.4
Tertiary	11.0	10.8
Total	8.7	9.8

Source: Psacharopoulos & Patrinos (2004)

1.2 A Glance at Developing Asian Countries

In the 1950s and 1960s, the development potential of Asia has been categorised as the worst among regions by World Bank. Nonetheless, the four East Asian Newly Industrialised Economies (NIEs, i.e. Hong Kong, South Korea, Singapore and Taiwan) and traditional four-ASEAN countries (i.e. Indonesia, Malaysia, Philippines and Thailand) emerged as high growth region in the 1980s and 1990s. Additionally, the emergence of China and India as high growth economies in the late 1980s had caused Asian countries become a focus for researchers to investigate the drivers behind it.

Yet, the previous research conducted there is no conclusive evidence regarding the important drivers of growth of developing Asian countries, thus leading to debates regarding the contribution of technological progress or TFP in the economic growth of Asian countries. Assimilation arguments claimed that the economic growth of Asia's economies is mainly driven by TFP growth which is made possible through technology transfer (Klenow & Rodriguez-Clare, 1997; Kim, 2001; Park & Ryu, 2006). In contrast, accumulation arguments claimed that Asia's growth was mainly due to capital accumulation (Young, 1994, 1995; Collins & Bosworth 1996; Kim & Lau 1996; Lau & Park, 2003). They found that the role of TFP growth in the economic growth is relatively small and doubt on the conventional belief regarding the contribution of TFP in Asian countries' economic growth.

Developing Asian countries have grown tremendously at an average of seven percent of annual GDP growth over the last 30 years. As shown in Figure 1.2, developing Asia's share of world output and trade has increased rapidly. The impressive economic performance of developing Asian countries was mainly contributed by their outward-oriented trade and proactive investment policy which encourage integration with the world economy (Keller, 1996, 2004; Lee & Hong, 2010).

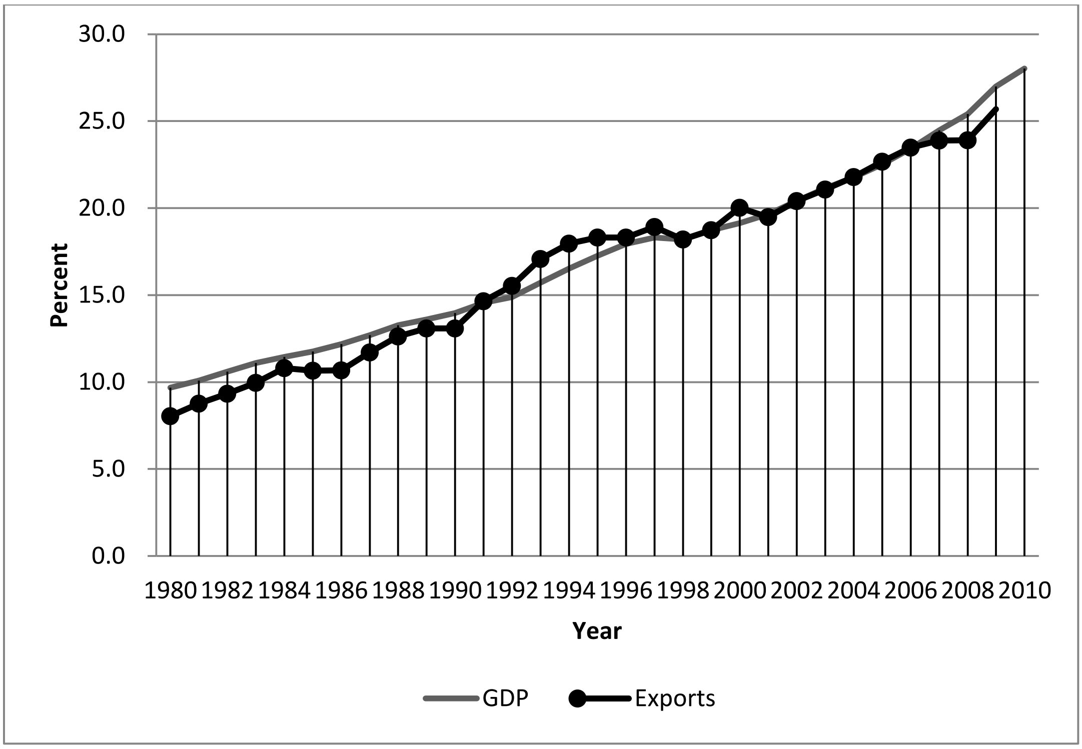

Figure 1.2
Developing Asia's Share of World GDP and Exports, 1980-2010
Source: Asian Development Outlook, Asian Development Bank (ADB), 2010

The high extent of global integration policy has provided developing Asian countries with the opportunity to intensify technological progress through technology transfer via FDI and imported technology. FDI and imported technology of developing Asian countries have increased tremendously over the decades as shown in Table 1.2 and Table 1.3, respectively. The FDI inflows to developing Asian countries have increased rapidly; for example, FDI inflows in China has raised from only US$57 million in 1980 to US$78,192.70 million in 2009 and imports of machinery and equipment increased from US$31,425 million to US$867,205 million from 1980 to 2009.

Table 1.2

FDI Inflow in Developing Asian Countries, 1970-2009 (US $ in current prices)

Country	**1970 (US$ million)**	**1980 (US$ million)**	**1990 (US$ million)**	**2000 (US$ million)**	**2009 (US$ million)**
Bangladesh	N.A	8.51	3.24	280.38	674.25
China	N.A	57.00	3487.00	38399.30	78192.70
India	45.46	79.16	236.69	3584.21	34577.20
Indonesia	145.38	180.00	1093.00	-4550.35	4877.37
Malaysia	94.00	933.90	2332.46	3787.63	1387.39
Nepal	0.03	0.30	5.94	-0.48	38.18
Pakistan	23.00	63.63	245.27	308.00	2387.00
Papua New Guinea	129.65	75.52	155.41	95.93	418.82
Philippines	-1.04	-106.00	530.00	2240.00	1948.00
Sri Lanka	-0.3	43.01	43.36	172.94	404.00
Thailand	42.8	189.86	2443.55	3365.99	4976.28
Vietnam	0.07	1.67	180.00	1298.00	7600.00

Note: N.A represents not avialable
Source: World Bank, World Development Indicators (WDI), 2014

The rapid process of globalisation and information and communication technology (ICT) provides developing countries with an easier access to new technologies from abroad has accelerated the rate of technological transfer in developing Asian countries (World Bank, 2008).

Table 1.3

Imports of Machineries and Equipments in Developing Asian Countries, 1990-2009

Country	**1990 (US$ million)**	**2000 (US$ million)**	**2005 (US$ million)**	**2009 (US$ (million)**
Bangladesh	897	739	5,248	7,126
China	31,425	184,581	624,959	867,205
India	5,772	13,471	49,466	98,593
Indonesia	12,635	12,491	22,578	56,312
Malaysia	27,496	17,564	153,035	139,893
Nepal	141	417	370	1,358
Pakistan	2,744	1,315	12,983	9,964
Papua New Guinea	613	463	N.A	N.A
Philippines	547	82,194	73,625	247,184
Sri Lanka	732	1,165	2,840	2,331
Taiwan	37,671	147,219	155,412	134,569
Thailand	58,063	58,063	88,501	94,174
Vietnam	N.A	7,063	15,052	37,087

Note: Import of Machineries and Equipments consist of machineries and transport equipment, office and telecom equipments, electronic data processing and office equipment, telecommunication equipments, integrated circuits and electronic components, and automotive products.

Source: World Trade Organization Statistic Database, 2014

The educational investment in developing Asian countries has increased over the decades. An educational investment measured by the public spending in education is the main force that drives the education sector. Table 1.4 shows the public expenditure on education[3] in selected developing Asian countries for the period 1970–2010.

[3] Public spending on education reflects the investment in pupils to provide them basic social and economic skills needed to be self sufficient. It consists of current and capital public expenditure on education by considering government spending on public and private educational institutions, education administration and subsidies for private entities.

Table 1.4
Government Spending on Education as % of GDP in Developing Asian Countries, 1970-2010

Country	**1970**	**1980**	**1990**	**2000**	**2010**
Bangladesh	N.A	0.94	1.58	2.38	2.24
China	1.46	1.93	1.67	1.90	3.66
India	N.A	N.A	N.A	4.25	3.32
Indonesia	2.64	5.62	0.99	2.46	2.99
Malaysia	4.28	5.62	5.11	5.97	5.11
Nepal	N.A	N.A	N.A	2.98	4.72
Pakistan	1.65	2.13	2.52	1.84	2.87
Papua New Guinea	N.A	N.A	N.A	N.A	N.A
Philippines	N.A	1.72	3.04	3.27	2.65
Sri Lanka	3.32	2.70	2.41	N.A	1.97
Thailand	3.07	2.57	3.09	5.41	3.75
Vietnam	N.A	N.A	N.A	N.A	6.29

Note: Data for Bangladesh in 2010 is 2009; for China data in 2010 is 2012; for Indonesia data in 1970, 1990 and 2000 are 1972, 1994 and 2001, respectively; for Philippines in 1990 and 2010 are 1995 and 2009, respectively. N.A is not available.
Source: UNESCO Institute for Statistics (http://stats.uis.unesco.org), 2014

Regardless of the remarkable growth performance of developing Asian countries for the past three decades, standards of living still well below of the advanced countries in which a significant income per capita gap is present between developing Asian countries and advanced countries as shown in Figure 1.3. Therefore, is important for developing Asian countries to enhance and sustain the economic growth momentum in the long-run in order to catch-up with advanced countries.

Human capital stock has been often highlighted as one of the critical factors that contribute to the well economic growth performance of developing Asian countries. This notion is supported by the record of the educational progress in these countries. Developing Asian countries has achieved rapid human capital development for the past four decades.

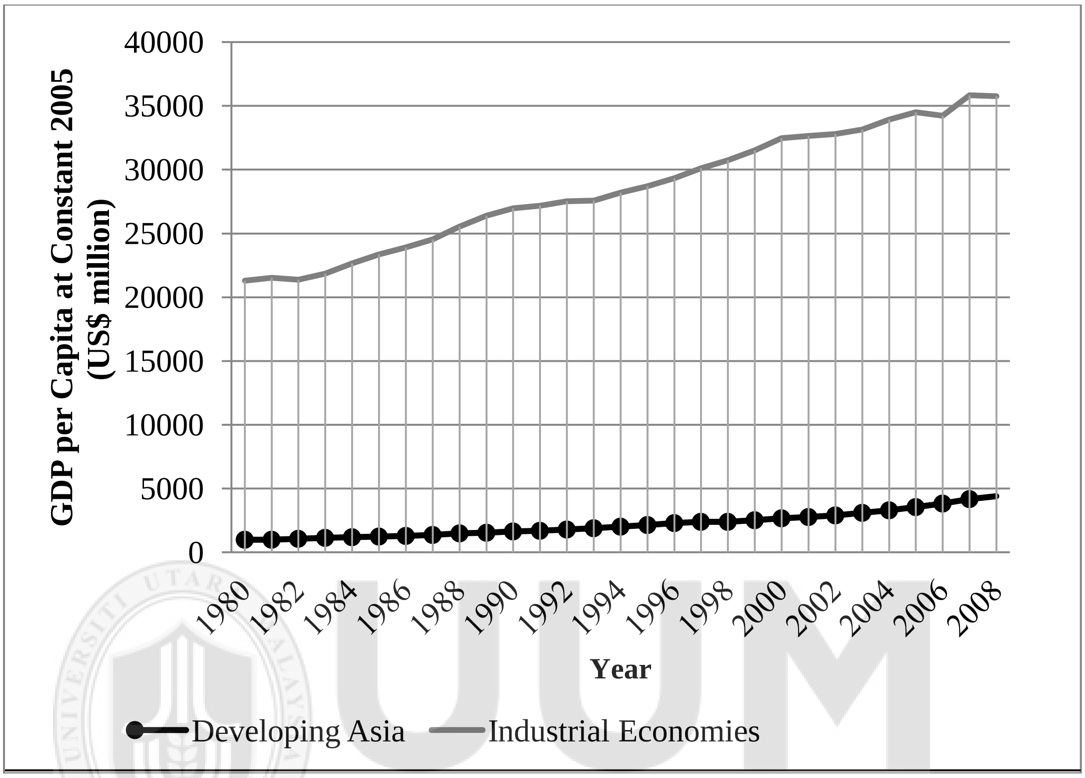

Figure 1.3
GDP per Capita, Developing Asian Economies versus Industrial Economies
Source: Asian Development Outlook (ADB), 2010

Generally, the public spending on education has increased over time in the developing Asian countries but it is still well below the internationally recommended minimum investment in education of six percent of GDP (except Vietnam). Over the past four decades, Malaysia has achieved a high percentage of public spending on education, at the average of five percent among the 12 developing countries. Steadily growing public spending on education has significant impact on increasing the educational attainment in the developing Asian countries.

Developing Asian countries also have shown an increasing trend in educational attainment for the past four decades as shown in Table 1.5. The average years of total schooling for the population aged 15 and above of developing Asia increased from 3.1 years in 1970 to 7.2 years in 2010 (i.e. an increase of 4.1 years).

Table 1.5
Educational Attainment of the Total Population 15 Years and Above: Developing Asian Countries, Advanced Countries and Developing Countries, 1970-2010

Country	Year	Average Year of Total Schooling
Advanced Countries	1970	7.64
	1980	8.74
	1990	9.55
	2000	10.52
	2010	11.3
Developing Countries	1970	3.35
	1980	4.37
	1990	5.28
	2000	6.33
	2010	7.20
Developing Asia	1970	3.13
	1980	4.09
	1990	5.00
	2000	6.10
	2010	7.20

Notes: The average years of total schooling for total population for advanced countries and developing countries are obtained from Lee and Francisco (2010) and developing Asia are author's calculation.
Source: Barro & Lee[4] (2010) and Lee & Francisco (2010)

Developing Asia's educational attainment level has been below the average years of total schooling in developing countries over the three decades (1970–2000) and has reached same level as the developing countries in 2010. However, the educational progress in developing Asia in the past four decades still did not manage

[4] The data includes average years of schooling for different education level among the population aged 15 years and over at 5-year intervals from 1950–2010.

to reach the same educational level of the advanced countries in 1970 as shown in Table 1.5.

Among the developing Asian countries, the average years of schooling in Sri Lanka in 2010 is the highest (10.51 years) as shown in Table 1.6. This is higher than the average year of schooling in the developing countries (7.2 years) and just slightly 0.8 year lower than advanced countries (11 years). China, the Philippines and Malaysia also showed an impressive education level at around 10 average years of total schooling. The increasing trend of educational attainment in developing Asia is likely due to the great improvement in the average years of primary and secondary schooling (Lee & Francisco, 2010). Tertiary education in the developing Asian countries still relatively low with less than one year of schooling in 2010. Although developing Asian countries has experienced rapid educational progress in the past four decades, the educational attainment level of some of them is still at a low level. For example, the average years of total schooling in India, Indonesia, Nepal, Pakistan and Papua New Guinea were less than six years.

The industrial revolution of developing Asia in the 1970s has increased women participation rate in the labour force. Improvement of gender inequality gap of schooling over the decades in the developing Asia countries has enhanced the economic opportunity of female. The increasing involvement of female workforce in the economic activities will increase productivity and foster technological development (Taeb *et al.*, 2005) as female education has higher positive returns in developing countries especially female with secondary education level (Psacharopoulos & Patrinos, 2004; Lloyd et al., 2005).

Table 1.6 presents the educational attainment data of the developing Asian countries by human capital composition and gender. In terms of gender educational attainments, the gender gaps in education have improved steadily for the past four decades but female educational attainment still lagging behind male educational level. Average years of female schooling and male schooling were 6.80 and 7.59, respectively in developing Asian countries in 2010. Nonetheless, the improvements of female educational attainment were varying across countries. Average years of female schooling in the Philippines and Sri Lanka are slightly higher than the average years of male schooling. For India and Pakistan, female education level still well below male education with more than with average of 2.5 years of schooling. The female education level has been greatly increased in primary and secondary levels in developing Asian countries over the past 40 years due to broader educational opportunities and increase in the female educational capital. Average years of female and male primary schooling increased by 2.4 and 1.25 years, respectively and average years of female and male secondary schooling increased by 1.74 and 1.56 years, respectively.

In addition, aggressive efforts have been taken by developing Asian countries to improve their tertiary education in both genders. Tertiary education has showed an impressive increment especially in female population, from the average of 0.04 year of schooling in 1970 to 0.30 year of schooling in 2010.

Table 1.6

Educational Attainment Trends of the Total, Female and Male Population Aged 15 Years and Above: Developing Asian Countries, 1970-2010

Country	Year	Educational Attainment for Female Population				Educational Attainment for Male Population				Average Years of Schooling for Total Population
		Average Years of Primary Schooling	Average Years Secondary of Schooling	Average Years of Tertiary Schooling	Average Years of Schooling	Average Years of Primary Schooling	Average Years Secondary of Schooling	Average Years of Tertiary Schooling	Average Years of Schooling	
Developing Asia	1970	1.86	0.52	0.04	2.43	2.84	0.91	0.07	3.82	3.13
	1980	2.44	0.83	0.07	3.33	3.39	1.34	0.10	4.83	4.09
	1990	3.03	1.21	0.12	4.37	3.82	1.63	0.17	5.62	5.00
	2000	3.61	1.71	0.21	5.54	4.32	2.09	0.25	6.66	6.10
	2010	4.24	2.26	0.30	6.80	4.81	2.47	0.32	7.59	7.20
Bangladesh	1970	0.55	0.09	0.00	0.63	1.83	0.64	0.04	2.51	1.62
	1980	1.19	0.28	0.01	1.47	2.64	1.00	0.05	3.70	2.63
	1990	2.08	0.71	0.05	2.84	3.13	1.28	0.11	4.51	3.70
	2000	3.01	1.41	0.09	4.52	3.55	1.83	0.13	5.50	5.02
	2010	3.65	2.31	0.12	6.08	4.25	2.23	0.19	6.67	6.36
China	1970	2.39	0.57	0.01	2.97	3.34	1.01	0.04	4.39	3.70
	1980	3.34	1.03	0.01	4.38	4.28	1.65	0.04	5.97	5.20
	1990	4.11	1.78	0.05	5.94	4.34	2.22	0.07	6.63	6.29
	2000	4.58	2.61	0.11	7.30	5.36	3.35	0.17	8.88	8.11
	2010	5.07	3.35	0.22	8.64	5.58	4.05	0.29	9.91	9.29

Table 1.6 (Continued)

India	1970	0.84	0.12	0.01	0.97	2.23	0.35	0.05	2.64	1.83
	1980	1.12	0.41	0.04	1.56	2.56	1.01	0.10	3.67	2.65
	1990	1.83	0.65	0.07	2.56	3.62	1.38	0.17	5.17	3.90
	2000	2.44	0.89	0.10	3.43	4.16	1.66	0.19	6.01	4.76
	2010	3.20	1.27	0.18	4.64	4.65	2.01	0.28	6.94	5.82
Indonesia	1970	1.90	0.20	0.01	2.10	3.15	0.44	0.02	3.60	2.84
	1980	2.51	0.39	0.01	2.91	3.60	0.74	0.03	4.37	3.64
	1990	2.51	0.92	0.04	3.47	3.28	1.36	0.07	4.72	4.09
	2000	3.73	0.85	0.05	4.62	4.22	1.14	0.08	5.44	5.03
	2010	4.34	1.24	0.09	5.67	4.68	1.43	0.12	6.23	5.95
Malaysia	1970	2.27	0.58	0.03	2.89	3.98	1.20	0.06	5.24	4.08
	1980	3.35	1.30	0.08	4.73	4.36	1.94	0.10	6.40	5.57
	1990	4.13	2.01	0.17	6.31	4.65	2.24	0.22	7.12	6.72
	2000	4.84	3.20	0.24	8.28	5.26	3.76	0.28	9.30	8.79
	2010	5.19	4.36	0.44	9.99	5.43	4.30	0.41	10.14	10.06
Nepal	1970	0.09	0.05	0.00	0.14	0.70	0.29	0.02	1.00	0.57
	1980	0.19	0.10	0.01	0.29	1.35	0.53	0.06	1.94	1.11
	1990	0.97	0.53	0.04	1.53	2.77	1.28	0.16	4.22	2.86
	2000	1.67	0.77	0.03	2.46	3.32	1.13	0.15	4.59	3.49
	2010	2.70	1.39	0.06	4.15	4.05	1.20	0.16	5.41	4.76

Table 1.6 (Continued)

Pakistan	1970	0.57	0.22	0.02	0.81	1.65	0.79	0.08	2.52	1.70
	1980	0.67	0.24	0.03	0.94	2.26	1.23	0.09	3.58	2.31
	1990	1.14	0.55	0.03	1.72	2.74	1.54	0.13	4.40	3.11
	2000	1.57	0.92	0.19	2.67	3.04	1.98	0.34	5.36	4.06
	2010	2.85	1.56	0.17	4.57	4.18	2.51	0.26	6.95	5.79
	2010	3.13	0.32	0.03	3.49	3.92	0.61	0.04	4.56	4.04
Philippines	1970	3.89	1.37	0.36	5.62	4.18	1.64	0.37	6.19	5.91
	1980	4.65	2.08	0.51	7.25	4.75	2.23	0.47	7.46	7.35
	1990	5.13	2.68	0.66	8.46	5.01	2.62	0.60	8.24	8.35
	2000	5.33	3.22	0.97	9.52	5.17	3.08	0.89	9.13	9.33
	2010	5.58	3.56	1.08	10.22	5.35	3.37	0.99	9.71	9.97
Sri Lanka	1970	3.83	1.89	0.03	5.75	4.71	2.31	0.05	7.07	6.44
	1980	4.36	1.86	0.02	6.24	4.93	2.15	0.03	7.12	6.69
	1990	4.89	2.93	0.17	7.98	5.21	3.07	0.17	8.45	8.22
	2000	5.23	4.14	0.43	9.80	5.42	4.19	0.39	10.00	9.90
	2010	5.41	4.52	0.58	10.52	5.53	4.51	0.46	10.50	10.51
Thailand	1970	2.49	0.24	0.02	2.75	3.15	0.43	0.04	3.62	3.19
	1980	2.91	0.57	0.10	3.58	3.39	0.80	0.13	4.33	3.95
	1990	3.62	0.92	0.17	4.70	3.93	1.05	0.20	5.18	4.94
	2000	3.93	1.30	0.22	5.45	4.26	1.51	0.21	5.98	5.71
	2010	4.60	1.86	0.45	6.91	4.88	1.99	0.38	7.25	7.07

Table 1.6 (Continued)

Viet Nam	1970	2.84	0.71	0.01	3.56	3.88	1.44	0.04	5.37	4.45
	1980	3.75	1.41	0.01	5.17	4.61	2.18	0.04	6.83	5.99
	1990	3.93	0.50	0.04	4.47	4.44	0.71	0.08	5.23	4.84
	2000	4.47	0.96	0.07	5.51	4.84	1.14	0.11	6.08	5.79
	2010	4.97	1.69	0.19	6.84	5.17	1.76	0.23	7.16	7.00

Source: Barro & Lee (2010)

1.3 Problem Statement

A stylised fact of economic growth is that, productivity growth is a relatively more important source in sustaining economic growth in the long run than rapid accumulation of physical capital due to the law of diminishing marginal returns to capital. As the developing Asian countries are in the path of transformation, they must increasingly depend on productivity to drive economic growth. This means that the key to sustain rapid growth thus lies in improving the TFP growth which is the main challenge of developing Asia in the long run (Park & Park, 2010).

The inconclusive results on the main driver of economic growth suggest carrying out further analysis into the TFP growth of Asian economies. Most of the past studies were confined to the developed Asian countries (i.e. Newly Industrialised Economies (NIEs)) and the traditional four-ASEAN countries (i.e. Indonesia, Malaysia, the Philippines and Thailand) which were looked at the pre-2000 period. However, as far as the study concerned, the sources behind the growth of developing Asian beyond the period 2000 are not extensively discussed by recent studies. This study attempts to investigate the role of TFP growth in the output growth of developing Asian countries for the period of 1970 – 2009.

Technology progress is perceived to be the main driver for economic growth. Given that most of the new technology innovation is concentrated in the advanced countries (Figure 1.1), thus, developing countries rely highly on technology transfer to obtain technology developed elsewhere. The importance of international technology transfer in determining the TFP growth has long been recognized (Grossman & Helpman, 1991; Coe, *et al.*, 1997; Eaton & Kortum, 1999; Howitt, 2000; Keller, 2004). Adequate macroeconomic and liberalization policies have accelerated the technology transfer in developing Asian countries as mentioned earlier. Such accelerated rate of technology transfer is anticipated to diminish the per capita income gap between developing and advanced countries (Lee, 2001) and eventually developing countries would be able to catch-up with advanced countries.

In spite of the theoretical anticipation, the persistent income gap between developing Asian countries and advanced countries has been observed (Figure 1.3). Thus, a high degree of global economic integration and participation of developing Asian countries does not seem to facilitate effective transfer of technology into the economy and apparently not sufficient for technology catch-up (Keller, 2004) and TFP improvement[5]. Insufficiency in the technology catch-up may have hindered the transformation process of developing Asian countries to high income countries and likely result in them falling into the Middle Income Trap[6] (ADB, 2010).

How effective are developing Asian countries in adopting foreign technologies? Differences in the ability of countries to absorb technologies developed elsewhere could be a significant determinant of the world income distribution (Pigliaru, 2003; Crespo-Cuaresma *et al.*, 2008) which highlights the importance of the absorptive capacity of effective technology transfer in developing countries. Accordingly, magnitude of technology transfer progress of developing countries is partly determined by the extent of its technological absorptive capacity (Gerschenkron, 1962), thus, in identifying the effectiveness of technology transfer performance, absorptive capacity must be examined to measure its influence on the technology transfer process.

[5] Framework on the technology transfer process and absorptive capacity in the developing countries by World Bank (2008) is presented in a form of chart in Appendix A1.
[6] Countries trap into the middle income trap if they fail to transform from a low-cost to high-intensive economy. This may cause them losing comparative advantages to compete with low-income and high-income countries.

To sustain further growth in the transition towards the high income level, a country depends more on technology intensive industries and high skilled workers (Lee, 2001; Tran, 2013) rather than non-technology intensive industries and unskilled workers. Lower education level (primary and secondary education) might lack of ability in supporting and sustaining economic productivity. Demand on workforce with advanced technological and managerial skills is increasing in the economic convergence process (Shaw *et al.*, 2011). However, the findings of the different education levels in facilitating technology transfer are ambiguous and inconsistent for developing countries especially on the role of higher education level.

Apart from the role of aggregate human capital on growth, gender-separate human capital effects on growth also have been emphasised by researchers (Benovat, 1989; Barro & Lee, 1994; Caselli et al., 1996; Barro, 2003; Self & Grabowski, 2004) and the results are not conclusive. According to labour economic literature, different types of education level may have different impact on economic growth (Hassan & Cooray, 2013) and in addition the rates of returns on human capital are varying not only for different education levels but also for gender aspect as asserted by Psacharopoulos and Patrinos (2004). Generally, the improvement of educational attainment of developing Asian does not only increase the average educational level but also reduces the gender education disparity. Female education at all levels has increased steadily over the decades in developing Asia as mentioned earlier and this in turn has induces the female labour participation rate and earnings which increase the accessibility and adoption of foreign technologies by female (Ainuddin *et al.*, 2005). Furthermore, female education in general is said important in improving the social and economic gains by seeing that female education has higher rate of return which may contribute more to productivity economy. Nevertheless, as far as the study concerns, not much attention has been given to the issue of gender human capital composition based absorptive capacity in enhancing TFP growth through facilitates technology transfer.

This study tests the related hypothesis based on a logistic technology diffusion model developed by Benhabib and Spiegel (2005) which involve a dampening effect of the diffusion process as the distance to technological frontier is increasing, implying that technological catching-up will be slower if a country is too far away from the technological frontier with low human capital level. In order to allow sufficient technological diffusion, a country must be equipped with adequate education levels. If the education levels are too low then the country will be left behind and diverge in the long run. Thus, this study attempts to address the gap in the literature by studying the effect of female and male educational attainment (the dual dimensions of human capital – level-specific education and gender) at different schooling levels, separately, on TFP growth using the framework of logistic technology diffusion model which has not been studied extensively in developing Asia's empirical literature.

1.4 Research Questions

International technology transfer by gaining benefit of the leading-edge technology and its role in stimulating productivity growth is an important issue in economic development. As innovation activities are overwhelmingly centred in the advanced countries, developing countries are highly dependent on imported technologies as their main sources of gaining new technological knowledge

(Hoekman *et al.*, 2005). Indeed, these technology absorption and adaptation processes foster technological change in developing countries. Trade openness policies and FDI are critical channels for developing countries in gaining foreign technology but not sufficient enough because there needs to be absorptive capacity and ability to adapt foreign technology, which is related to human capital endowment (Durlauf & Johnson, 1995).

There are four different research questions to be addressed in this study, namely:

1. to what extent does TFP or technology progress contribute to the output growth in developing Asian countries?
2. does autonomous technology transfer occur in developing Asian countries?
3. does skilled human capital has significant impact on TFP growth of developing Asian countries?
4. is there any direct impact of gender human capital on TFP growth (innovation) of developing Asian countries?
5. is there any significant impact of gender human capital based absorptive capacity in the technology transfer process on TFP growth of developing Asian countries?

1.5 Objectives of the Study

The general objective of this study is to examine the absorptive capacity of human capital in the technological transfer process in enhancing productivity growth in the developing Asian countries.

The specific objectives are:

1. to analyse the pattern of TFP growth in the developing Asian countries.
2. to examine the effect of autonomous transfer on TFP growth.
3. to examine the impact of skilled human capital on TFP growth.
4. to investigate the direct impacts of gender human capital (innovation) on TFP growth.
5. to examine the effects of gender human capital based absorptive capacity in the technology process on TFP growth.

1.6 Scope of the Study

This study attempts to examine the contribution of TFP growth on economic growth and the impact of absorptive capacity on the process of technology transfer and TFP growth of developing Asian countries. The technological absorptive capacity is measured in terms of human capital using panel data analysis over the period of 1970 to 2009 for the developing Asian countries. This study only concentrates on the role of human capital based absorptive capacity in the technology transfer process, and only 12 developing Asian countries have been included in the sample of study due to the limitation of data availability.

1.7 Significance of the Study

Asia's remarkable high economic growth has been considered a "miracle" in the 1990s by the World Bank. Due to this, several empirical studies have investigated the sources of growth of Asian developing economies which mainly focus on the NIEs. This research pays attention on the growth patterns across developing Asian countries by not including the NIEs in the samples as in the previous studies and extending the period to post-2000. On the other hand, the growth of the developing Asian countries also has received less attention in the economic literature whereby research just focused on the case of fast growth countries such as China and India, the source of growth of other developing Asian countries (e.g. Bangladesh, Sri Lanka, Nepal and Vietnam) were not much reported by the empirical studies. Furthermore, controversies occur on the role of technical progress or TFP in the rapid and sustained economic growth of the Asian economies. This study attempts to enrich the literature by analysing the patterns of TFP growth of developing Asian countries.

Investigating cross-country technology transfer as a scope for further study was emphasized by Islam (2009). A better understanding of the nature of technology transfer is able to explain the question of why some countries grow faster while others do not. Technologically backward countries may grow faster than more advanced countries (Gerschenkron, 1962), however, it is subject to some conditions as it requires resources to adapt new technologies as technological knowledge is tacit, thus, technological adoption and imitation process is not automatic (Howitt, 2000), and the increasing complication of new products needs considerable investment in knowledge (human capital) and implementation of effective policies to absorb the new technologies effectively (Howitt & Mayer-Foulkes, 2005, World Bank, 2008).

To reap the benefits of new technology from abroad, developing countries must be equipped with adequate absorption capacity to exploit the technology transfer process. Countries that are better at absorbing foreign technology are able to experience faster TFP growth as highlighted by various empirical studies (Abramovitz, 1986; Hall & Jones, 1999; Benhabib & Spiegel, 1994; Keller, 1996, 2004). As developing Asian countries are in the transformation process towards high income countries, effectiveness of technology transfer may drive these countries catch-up to the technological frontier. This study adds to the empirical literature on technology transfer by investigating the role of gender human capital based absorptive capacity in the developing Asian countries.

This study investigates cross-country technology transfer and absorptive capacity on TFP growth by applying different specifications. It contributes to the growth and development literature by presenting new empirical evidences of the alternative hypothesis that contrary to Vandenbussche *et al.* (2006) theoretical assumptions on the role of skilled workers (represented by tertiary education) in the technology transfer process for developing Asian countries to catch-up with the technological frontier using logistic technology diffusion model. In addition, only a few studies, if any, have examined the impact of gender-separate human capital based absorptive capacity at different education levels on TFP growth in the technological transfer model. A priory the rates of returns on human capital are varying not only for different education levels but also for gender aspect.

The persistent weakness in technological absorptive capacity may constrain further technological progress in the developing countries. Therefore, by studying the sources of economic growth and the fundamental determinants of absorptive capacity – gender separate-human capital composition – in formulating the technological convergence process and TFP growth, developing Asian countries would be embark to the proper directions and policy in improving the educational attainment especially in the aspect of gender education disparity and higher education to ensure effectiveness of technology transfer and further converge to high income countries.

1.8 Organisation of the Study

This study is organised as follows. Chapter 1 discuss the background of the study. Chapter 2 provides the related literature reviews. In Chapter 3, the theoretical and empirical model is discussed and the estimation methods applied in this study. Chapter 4 performs the empirical findings o the study in favour of the hypothesis of this study. Chapter 5 concludes the discussion and presents some policy implication of this study. Moreover, the suggestions or future research is provided.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides insights into the present study by reviewing previous research concerning the theory of TFP on economic growth, the issue of TFP growth in Asian economies, the theoretical and the empirical evidence of human capital on TFP growth. Reviewing related literature involves examining or reviewing developments in theory as well as empirical works in the area related to the present study.

2.2 TFP and Economic Growth

Smith (1776) argued that forces of economic growth were driven by freeing market agents. In particular, technological process is driven by the consequences of the division of labour, rather than technology being an external driving force of productivity. He clearly expressed "the division of labour as the fundamental lynch pin of productivity growth" by stating it in *The Wealth of Nations* that "the greatest improvement in the productive powers of labour, and the greater part of the skill, dexterity, and judgement with which it is directed, or applied, seem to have been the effect of the division of labour" (Smith, 1776, p.13).

Ricardo (1815) highlighted investment in machinery and accumulation of capital as the basic forces in the economic growth process. In the Ricardian analysis, the rate of capital accumulation regulates the demand for labour and the marginal product of capital and labour falls due to diminishing marginal return. Ricardo argued that diminishing marginal returns can be offset by technological progress. The Classical economists also realized that the market forces development might result in inequalities in the development process. As economies expand, some agents gain due to new opportunities and some lose is perceived by Schumpeter (1954) as a process of "creative destruction". Thus, according to Schumpeter, income between sectors and groups diverges; however, economic growth will converges to stationary steady state of per capita income in the long run.

The Classical theorists have postulated that the level of output is a function of the stock of capital, labour force, land and technology level. This postulation can be represented by the production function which can be written as $Y = f(K, N, L, A)$, where Y = output, K = capital, N = labour force, L = land and A = technology level. In classical views, technological progress is restricted by capital accumulation because it was capital-absorbing and thus capital accumulation is a precondition for a stationary technological progress.

The basic Neoclassical model of Solow (1956) and Swan (1956) focused on capital accumulation. In the neoclassical growth model, a simple production function expresses that output was derived from two main inputs – labour and capital. Under the assumption of diminishing returns in the Solow-Swan growth model, when an economy keeps accumulating additional capital, this will eventually cause its per capita growth to drop to zero. However, the historical data show that output per capita increases continuously over a long period of time. Due to this inconsistency, Solow added an important variable exogenously to the model, so-called labour-augmenting technological change. The long-run growth rate is exogenously determined by technological progress. Technology increases productivity through increasing labour productivity. This exogenous technological change offsets the diminishing return and it is this variable that explains the rate of growth over a long period of time. Thus, economic growth is determined by the technological change that comes from outside the model.

Additionally, convergence is the most important empirical implication of the Neoclassical growth theory. In terms of productivity, the Neoclassical growth model suggests that a poor country should grow faster than a rich country under the assumption of diminishing returns, other things equal. Countries with different initial levels of output will grow at different rates. Countries with low initial levels of output should have relatively higher returns from additional investments than those with high levels of output.

Nonetheless, the Neoclassical growth theory in the 1950s and 1960s did not identify the major sources of growth sufficiently. Economists continued to find alternate ways to account for the forces of economic growth over time. The new growth theory is more relevant in studying cross-country patterns of income especially for developing countries and it provides an understanding of economic growth in terms of factor inputs. The new growth theory or so-called endogenous growth theory provides the foundation for answering why growth rates are different across countries. Any auxiliary explanatory factors can be applied in the new growth model to render technological progress endogenous in the production function. Theories of endogenous technology refer to a myriad of country factors that determine long-run technology growth such as R&D policies (Jones 1995), technology transfer (Fagerber, 1994; Eaton & Kortum, 1999; Howitt, 2000) and the accumulation of human capital (Lucas, 1988; Romer, 1990; Aghion & Howitt, 1998).

As the name implies, the endogenous growth theory attempts to endogenize the role of technological change into the model, which was put as exogenous in the Neoclassical model. New technological discoveries and the spillover effects on the economy can never be understood because one discovery can benefit other areas explicitly, and this is not always understood or even recognized (Cortright, 2001; Barro, 2001). This means that knowledge externalities occur in the research and development process. Hence, technological change causes increasing returns instead of decreasing returns as assumed in the Neoclassical growth model. Capital can be utilized more efficiently whereby technology offsets decreasing returns and allows notionally infinite growth possibilities.

The new growth model started with a seminal paper of Romer (1986). In the paper, Romer explained that persistent economic growth is driven by knowledge externalities. He dropped the diminishing returns assumption and used the constant rate of technology and population to show an increasing growth in per capita income, which may increase without upper bound. The rate of technological change is treated as endogenous in his model. He proved that investment in knowledge will cause increasing returns to scale and positive externalities. Investment in R&D by firms will create new products in the market, which will increase the stock of knowledge and lead to the invention of new products further. In addition, international trade and FDI can have positive implications on growth by allowing the transfer of knowledge and technology, and positive production externality especially from developed countries to developing countries. In terms of productivity, developing countries can grow faster than developed countries because of productivity catch-up through technology adoption.

2.3 Human Capital and Economic Growth

The importance of human capital as a determinant of economic growth has long been recognized by researchers. The theory of human capital initiated in the 1960s by Schultz (1961) and Becker (1964) was envisaged in microeconomic perspective which has subsequently been applied in macroeconomic perspective. Schultz (1961) initiated the idea on return-on-investment by treating training and education as investment and underlined the cost-benefit analyses on it. Training and education generate future benefits in terms of higher income and productivity as the increase in national income for Western countries was due to human capital investment. Becker (1964) developed a general human capital theory that human capital accumulation through education or training is able to increase the productivity of workers by delivering constructive knowledge and skills which will increase workers future income and thus lifetime earnings. He classified human capital into general and specific training. General training or education increases marginal product of workers and the cost will be borne by workers not firms. Workers are willing to bear the cost as general training would increase future earnings. However, firms would support the cost of specific training because firms would benefit more from the higher productivity not labour.

Human capital has been incorporated as an important factor in determining economic growth with the human capital augmented Solow (1956) growth model. New endogenous growth model also incorporates human capital as a determinant of economic growth by endogenizes the sources of growth. The effect of human capital on economic growth has been debated aggressively since the 1980s in the endogenous growth theory. The mixed findings on the impact of human capital on economic growth/ productivity needed more investigation as emphasized by Easterly and Levine (2001) that there is a need for further studies to be done in investigating the relationship between education and economic development. Romer (1986), Lucas (1988), Barro (1991) and Rebelo (1991) are among the earlier studies that examine the effect of human capital on economic growth. There are two different ways to integrate human capital into economic growth model. One is by Lucas's idea about the role of human capital accumulation as the mechanism of growth. Another mode is the role of human capital stock in the innovation and technology transfer process.

2.3.1 Human Capital Role in Theoretical Model of Economic Growth

2.3.1.1 Main Characteristics of the Solow Model

The Solow's standard neoclassical growth model which was developed in the 1950s was based on the aggregate production function $Y_t = f(K_t, A_t L_t)$, where Y is total output, K is capital, L is labour and A is labour-augmenting technology, thus AL refers to effective labour. The production function has assumptions constant returns to scale and decreasing returns to each input. The dynamic of the model indicates that the stock of capital depreciates at a constant rate and labour and level of technology grow at exogenous exponential rates.

In the Solow model, without technological progress, growth will eventually cease due to diminishing returns. Thus, the economy converges to steady-state at the exogenous rate of technological progress. Consequently, conditional changes in the rate of saving or population growth have no effects on the economics in the long-run.

2.3.1.2 Exogenous Growth Model – The Human Capital Augmented Solow Model

Mankiw *et al.* (1992) extended the Solow model by including human capital as an input into a standard Cobb-Douglas production function with labour augmented technological progress which is called as human capital augmented Solow model $Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$ where Y is output, K is physical capital, H is human capital stock, L is labour and A is technology level and AL is called as effective labour. The production function exhibits constant returns to scale and diminishing return to capital under the assumption $\alpha + \beta < 1$. Their model assumes that investment in human capital and physical capital is done by foregoing consumption (represented by s_K and s_H as fraction of income donate to the accumulation of physical capital and human capital), the exogenous growth rate of the population and technology level are n and g, respectively, and physical and human capital depreciates at δ rate.

At steady-state level, physical and human capital per effective worker is $\hat{k}^* = \left(\frac{s_K^{1-\beta} s_H^{\beta}}{n+\mathrm{g}+\delta}\right)^{\frac{1}{(1-\alpha-\beta)}}$ and $\hat{h}^* = \left(\frac{s_K^{\alpha} s_H^{1-\alpha}}{n+\mathrm{g}+\delta}\right)^{\frac{1}{(1-\alpha-\beta)}}$, respectively. With the diminishing returns to capital (physical and human capital) assumption, output per worker and capital per worker grow at the exogenous rate of technological progress g. Therefore, in Mankiw et al. (1992) model, the steady state income per capita level is positively associated with the physical and human capital investment rate in which an increase in the human capital accumulation will cause the steady-state income level move upwards. They also predicted conditional convergence in the model that a country farther away from its steady state tends to have higher growth rate. Therefore, a country's rate of economic growth is determined by the initial level of income and determinants (e.g. rate of investment in human capital) of its steady state.

2.3.1.3 Endogenous Growth Model – Human Capital Accumulation

In exogenous (Neoclassical) growth model, the long-run growth is determined exogenously. In endogenous (new) growth model, sources of growth is determined within the model and technological change is not an unexplained residual but is included in the growth model as one of the determinants of economic growth. There are two distinct methods to integrate human capital in endogenous model e.g. accumulation of human capital by Lucas (1988) and stock of human capital by Romer (1990).

Lucas (1988) treated human capital accumulation as an important factor in the production function, thus government should increase education level of the population to enhance economic growth. In Lucas growth model, there are two important variables that one managed by individuals in maximizing their life-time utility, namely consumption level that influence the physical capital accumulation and time allocation between work and skill acquisition that influence individual's future productivity. Lucas growth model is $Y_t = AK_t^{\beta}(u_t h_t L_t)^{1-\beta} h_{a,t}^{\gamma}$, where Y, A, K and L are output, technology, capital and labour, respectively, u is the fraction of time allocated to work by an individual, h is the skill level of individuals and h_a which represents the average human capital in the economy and h_a is the average positive external effect of human capital. Lucas model assumes that the fraction of time allocated to the accumulation of human capital, $1 - u_t$ is associated with the growth of human capital as $\frac{\dot{h}_t}{h_t} = \delta(1 - \mu)$ where δ is the maximum achievable growth rate of h. Thus, growth is driven by human capital accumulation in the Lucas model whereby higher human capital accumulation has a rate effect in which more time allocated to human capital accumulation would lead to increase of growth, not fraction of income as in Mankiw *et al.* (1991) model. This contradicts with Mankiw *et al.* (1992) augmented human capital model that higher human capital only has a level effect instead of a rate effect in the Lucas model. Moreover, the state steady level in Lucas growth model depends on the externality effect of human capital in which $\gamma \neq 0$.

2.3.1.4 Endogenous Growth Model – Stock of Human Capital and Technological Progress

The idea that human capital may have significant absorptive capacity on foreign technologies was initially acknowledged by Nelson and Phelps (1966). They suggested that countries with a large stock of human capital have high ability to absorb new technological knowledge developed elsewhere based on the argument that "the better educated farmer is quicker to adopt profitable new processes and products since, for him, the expected payoff from innovation is likely to be greater and the risk likely to be smaller" (p. 70). In view of that a higher level of educational attainment would increase the extent of technology transfer and thus facilitate countries lagging behind catch-up to the technology frontier.

The idea that technology diffusion process of a country depends on its distance from the technological frontier has been originally highlighted by Gerschenkron (1962) as an "advantage of backwardness" in which the potential of growth for technologically backward countries is greater than technologically advanced countries due to their advantages of lower effective production costs (Howitt, 2000).

A theoretical model of technology transfer developed by Nelson and Phelps (1966) showed that productivity growth depends on the interaction of human capital and the gap between the technology in practice and the theoretical level of technology (technological frontier) that affects the extent and the speed of absorbing new technology. In their model, human capital acts as absorptive capacity in facilitating technology transfer. A higher human capital level has greater technological absorptive capacity in absorbing and adopting higher technology level. Hence, Nelson and Phelps (1966) emphasised that "investment in humans" needed education to exploit and absorb new technologies effectively by pointing out that education enhances the ability to obtain, interpret, and understand information that important for better job performing. Thus, absorptive capacity is important in absorbing new technologies developed abroad. Abramovitz (1986) claimed that a technologically backward country is not going to catch-up unless it is equipped with sufficient social capital ability in terms of education (Abramovitz, 1986). Furthermore, Keller also (1994, 2004) emphasised that technological absorptive capacity was an essential factor contributing to the differences in the ability to assimilate and exploit foreign technology across countries.

Technological follower countries with a high investment in human capital tend to grow faster because their technological absorptive ability is higher and this may lead them to catch-up more rapidly to the global technological change. Thus, countries with a higher initial stock of human capital experience a higher rate of initiation and adaptation of new technologies and ideas and tend to have higher growth rate. An example is Japan after World War II. Japan was able to rebuild its economy by absorbing technologies from abroad and further apply it in developing new products and ideas through its human capital development.

On the other hand, Romer (1990) treated technology endogenously in the growth model rather than exogenously as in the neo-classical model by emphasising the role of "learning by doing" in promoting the growth of a country. Romer (1990) emphasised the role of human capital stock in the innovation process as R&D activities require skilled workers. There are three sectors in Romer's model: a final-good sector, an intermediate goods sector and a research sector in which the research sector uses human capital to produce new capital goods for intermediate-goods sector and further the final-goods sector. Hence, the final function for the final sector is $Y = H_{\gamma}^{\alpha} L^{\beta} \sum_{i=1}^{A} x_i^{1-\alpha-\beta}$, where Y is output, L is labour, H_{γ} is human capital employed in production, A is the stock of knowledge and x_i is the intermediate capital product. In the equation, intermediate capital goods depend on the stock of knowledge. In Romer's model, growth is sustained by the expansion of stock of knowledge that creation of new knowledge depends on the allocation of human capital to the research sector which is expressed as $\frac{\dot{A}}{A} = \delta H_A$, where H_A is human capital involved in research. This indicates that rate of technological progress is determined by the stock of human capital in the research sector. In other words, an increase in the human capital stock will augment the economic growth rate.

2.4 Theoretical Framework

2.4.1 The Standard Growth Accounting Framework

The analysis of the sources of growth was initially developed by Solow (1957). Solow decomposed output growth into the growth of labour, capital and a residual, the last of which is commonly referred to as the "Solow residual" and interpreted as a measure of the contribution of technological progress to growth. To calculate the contribution of different input factors to economic growth, the conventional Cobb-Douglas production function with constant returns to scale is used as follows:

$$Y_t = A_t K_t^{\propto} L_t^{1-\propto} \tag{2.1}$$

where Y is aggregate output, K is physical capital stock, L is labour , A is TFP and $0 < \alpha < 1$ is the share of output with respect to the physical capital stock or the capital share.

There are two factor inputs affecting total output in the production function, thus, economic growth rates can decomposed into contributions from two input factors: capital, labour. TFP is residually calculated as follows:

$$A = \frac{Y_t}{K_t^{\alpha} L_t^{1-\alpha}} \tag{2.2}$$

This equation suggests that the value of A_t can be computed once the values of Y_t, K_t and L_t and α are provided. While the values of Y_t, K_t and L_t can be obtained directly from the data, the value of α needs to be estimated in some fashion. To begin with, there is no obvious way of choosing α. It turns out, however, that α can be interpreted under the additional assumption that firms operate in the perfect competition condition in the economy. To illustrate this, one has to conceive the profit maximisation problem of a firm using Equation (2.1) that rents capital at the rental rate, r_t, and hires labour at the wage rate, w_t:

$$\max_{K_t,L_t}\{A_t K_t^{\alpha} L_t^{1-\alpha} - r_t K_t - w_t L_t\}$$

The first-order conditions of the problem require the conditions that the factor prices equal the marginal product of each factor input:

$$r_t = \alpha A_t \left(\frac{L_t}{K_t}\right)^{1-\alpha} \quad (2.3)$$

$$w_t = (1-\alpha) A_t \left(\frac{K_t}{L_t}\right)^{\alpha} \quad (2.4)$$

From these first-order conditions, α and $(1-\alpha)$ can be expressed as follows:

$$\alpha = \frac{r_t K_t}{Y_t} \quad (2.5)$$

$$1-\alpha = \frac{w_t L_t}{Y_t} \quad (2.6)$$

which means that α and (1 – α) can be interpreted as, respectively, the capital share and labour share of output (i.e. the fraction of output used to pay capital and labour). Once the capital and labour shares have been computed, TFP values can be calculated using Equation (2.2).

2.4.2 Technological Catch-up Model

In addition to factor accumulation, technological progress plays an important role in growth. For developing countries, technology diffusion of foreign technology is the main source that enhances their technological progress. Gerschenkron (1962) addressed the importance of technology diffusion based on his statement that "industrialization always seemed the more promising the greater the backlog of technological innovations which the backward country could take over from the more advanced country" (p.6). The technological catch-up model developed by Nelson and

Phelps assumes that a country's technology level absorptive ability is stated with scale effects. Nelson and Phelps (1966) expressed technological progress in a general form of equation as:

$$\Delta(A) = \frac{\dot{A}}{A} = \emptyset(HC)\left[\frac{A^{max} - A}{A}\right] \quad (2.7)$$

where A is the technology level of a follower country, $A^{max}$is the technological level of the leading country or technological frontier[7], and $\emptyset(HC)$ denotes a function of absorption capability in terms of human capital. This equation has been commonly referred by researchers as the technological catch-up effect (e.g., Hanson & Henrekson, 1994; Islam 2009).

By assuming that A^{max} grows at an exogenous constant rate, g, the growth of A is equal to g in the long run (which is solved by differential equation (2.7) and $\frac{dA^{max}}{dt} = gA^{max}$). As shown in Figure 3.1, if the growth rate of A equals the growth rate of A^{max}, the right-hand side of equation (2.7) is changing which means that the growth rate of A is changing as well.

This implies that a follower country with the technology ratio $\left(\frac{A}{A^{max}}\right)$ which is below the long-run equilibrium level $\left(\frac{\emptyset}{(\emptyset+g)}\right)$ will grow at faster rate (relatively higher than g), whereas a country that the technology ratio is above the long run equilibrium level will grow lower than g.

[7] The idea of the theoretical level of technology, $T(t)$, was introduced by Nelson and Phelps (1966) by defining it as "…the best-practice level of technology that would prevail if technological diffusion were completely instantaneous… the theoretical technology level advances exogenously at constant exponential rate, : $T(t) = T_o e^{\lambda t}$ $where$ $\lambda > 0$ (p.71)."

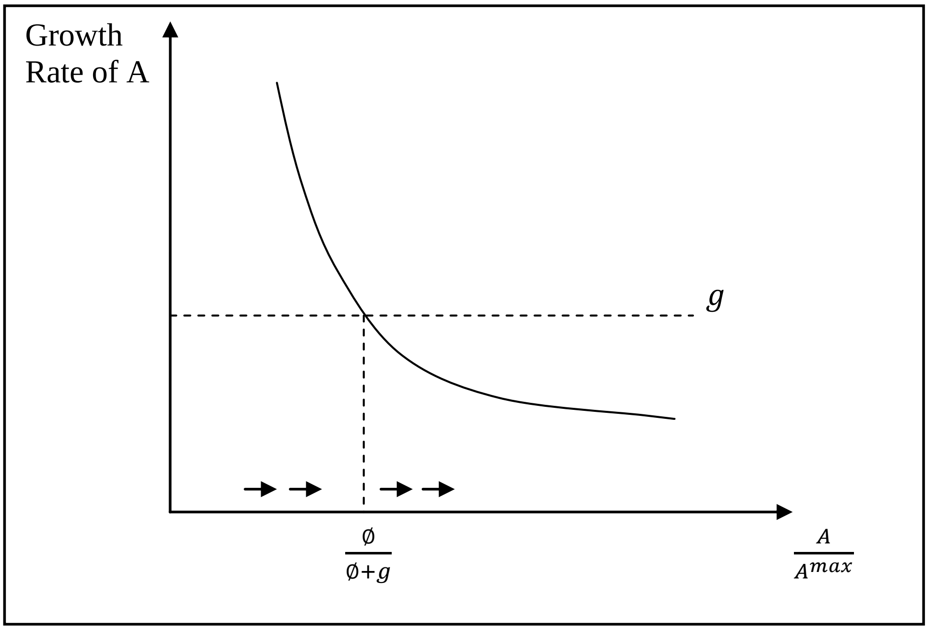

Figure 2.1
A Monotonic Technology Model (Rogers, 2004)

2.4.3 Confined Exponential Technology Diffusion Model

Based on Nelson and Phelps (1966) argument, treating human capital as a factor of production would misspecify the role of human capital since it limits its contribution to the marginal product of labour and ignores the capacity of human capital in adopting new technology which may affect the TFP growth. Following the endogenous growth model, Benhabib and Spiegel (1994) asserted that the level of human capital may affect TFP directly (through innovation) and indirectly (through the rate of the technology catch-up process). They express technological progress, ΔA_{it}, as:

$$\Delta A_{it} = \frac{\dot{A_{it}}}{A_{it}} = g(HC_{it}) + c(HC_{it})\left[\left(\frac{A_t^{max} - A_{it}}{A_{it}}\right)\right]$$

$$= g(HC_{it}) + c(HC_{it})\left[\left(\frac{A_t^{max}}{A_{it}} - 1\right)\right] \quad (2.8)$$

where A_{it} is the TFP of the followers country, A^{max} is the TFP of the leading country. The direct effect of the level of education, HC_{it}, in country i on TFP growth is represented by component $g_i(HC_{it})$, and the indirect effects is indicated by the rate of technology diffusion from the leading country max to country i that is $c_i(HC_{it})\left[\left(\frac{A_t^{max}}{A_{it}} - 1\right)\right]$ in which $g, c > 0$. Thus, the level of education affects the rate of technology catch-up which is represented by the technology gap $\left(\frac{A_t^{max}}{A_{it}} - 1\right)$ that gets closer to the technological frontier.

The technology diffusion process expressed by Equation (2.8) is known as the confined exponential model of technology diffusion. According to Equation (2.8), the level of human capital enhances the ability of a country to develop domestic technological innovation (direct effect) and also its ability to catch-up to technological frontier, A_t^{max} by adapting and adopting technologies developed elsewhere (indirect effect).

2.4.4 Logistic Model of Technology Diffusion

Benhabib and Spiegel (2005) proposed the logistic model of technology diffusion by modifying Equation (2.8). The logistic model of diffusion not only highlights the interaction of human capital and the technology gap but also the rate of catching-up to the technological frontier is moderated by the distance to the frontier technology because of technology clusters or inappropriateness with recipients' local technology absorptive capacity condition[8]. The logistic model of diffusion is specified as follows:

[8] Basu and Weil (1998) mentioned that new technology could not be instantaneously "appropriate" for the following countries if there are big variations in factor ratios between leading and following countries.

$$\Delta A_{it} = \frac{\dot{A_{it}}}{A_{it}} = g(HC_{it}) + c(HC_{it})\left[\left(\frac{A_t^{max} - A_{it}}{A_{it}}\right)\right]\left[\frac{A_{it}}{A_t^{max}}\right]$$

$$= g(HC_{it}) + c(HC_{it})\left[\left(1 - \frac{A_{it}}{A_t^{max}}\right)\right] \quad (2.9)$$

Equation (3.9) implies that technology catch-up term is moderated by the distance to the frontier, $\left[\frac{A_{it}}{A_t^{max}}\right]$. The difference between Equation (2.8) and (2.9) is essentially the existence of the additional term $\left[\frac{A_{it}}{A_t^{max}}\right]$ which dampens the rate of technology diffusion when the distance to the technology frontier increases (Benhabib & Spiegel, 2005). Thus, technological catch-up may be slower if there is a large gap between lagging country and frontier country or for countries that are closer with the technology frontier. Technological catch-up term, c_i, is expected to be an increasing function with the level of human capital, i.e. $c_i{}'(.) > 0$.

Assume $g \; and \; c$ are constant, the solution of Equation (3.9) in the limit can be expressed as[9]:

$$\lim_{1\to\infty} A_t \Big/ A_t^{max} = \begin{pmatrix} \frac{(c_i+g_i-g^{max})}{c_i} & & (c_i + g_i - g^{max}) > 0 \\ \frac{A_{i0}}{A_o^{max}} & if & (c_i + g_i - g^{max}) = 0 \\ 0 & & (c_i + g_i - g^{max}) < 0 \end{pmatrix} \quad (2.10)$$

where the steady state growth relationship shows that the ability of a country to catch-up with the technology frontier depends on the catch-up rate and the difference in the innovation growth rate between leader country and follower country, $g_i - g^{max}$. If the catch-up rate, c_i, exceeds the stated difference growth rate, that is $(c_i + g_i - g^{max}) > 0$, showing that the leader country has an ability to pull the follower countries along, then the follower countries' growth rate will converge. In

[9] The derivation is showed in Appendix A1.

order to keep within the gravitational pull path, high skilled human capital (tertiary education) is more efficient than lower skilled human capital (primary and secondary education) as the high skilled human capital can induce the catch-up faster and, thus, allows the catch-up rate to exceed the innovation differential growth rate.

In contrast, if a country lacks absorptive capacity in absorbing and adopting new technology whereby $(c_i + g_i - g^{max}) < 0$, then it is not able to catch-up and growth rates will diverge. Thus, the logistic type of technology diffusion shows that countries with very low human capital level of absorptive capacity will be left behind and it will be "convergence club" as technology diffusion does not take place effectively in the follower country.

Logistic model shows that a country's technology absorptive capacity is related to the distance from technological frontier in determining whether the country is converging or diverging. Intuitively, a high skilled worker would outperform the unskilled worker in absorbing and adapting new technological knowledge.

2.4.5 A Nested Specification

Benhabib and Spiegel (2005) nested specification[10] of both logistic $(s = 1)$ and confined exponential $(s = -1)$ diffusion of technology is shown as follows:

$$\Delta A_{it} = \left(g + \frac{c}{s}\right) HC_{it} - \frac{c}{s}(HC_{it}) \left[\frac{A_{it}}{A_t^{max}}\right]^s \tag{2.11}$$

Benhabib and Spiegel (2005) proved that a linear logistic technology diffusion model is more favourable than confined exponential model.

[10] The derivation of the nested specification is shown Appendix A2

2.5 Concept of Technology Transfer

Roessner (2010) defined technology transfer as "the movement of know-how, technical knowledge, or technology from one organizational setting to another (p. 1)." This implies that technology transfer is not just limited to capital good movement but also includes the application and adaptation of technological knowledge. Manfield (1975) divided technology transfer into two mainstreams–vertical and horizontal technology transfers. Vertical transfer refers to the transfer of technology that alters basic and technical knowledge by applying related knowledge to development and further to production while horizontal transfer refers to the transfer of technological knowledge from one place to another place through different channels of diffusion (Ramanathan, 2009). Vertical and horizontal technology transfer are also referred to as internal transfer and external transfer, respectively (Souder, 1987). In the growth and development literature, the concept of technology transfer is generally referred to as the transfer of technology across countries or between suppliers and users (Carls, 1985). This study focuses on first mode of technology transfer, i.e. the international technology transfer across countries. Hayami and Ruttan [11] (1971) recognised the capacity of technology transfer as the ability of technology transfer, skill and competence (referred to as know-how) developed in the human force to improve and adapt technological knowledge developed elsewhere.

[11] According to Hayami and Ruttan (1971), there are three stages of technology transfer: 1] material transfer, 2] design transfer and 3] capacity transfer.

2.6 What is Human Capital?

The early growth development economists tend to consider only physical capital in the growth model. Starting in the 1960s, the definition of capital has been expanded to include human capital and gained prominence in the 1980s until today. The contemporary theory of human capital has been discussed since the 1960s and 1970s by Schultz (1960, 1961), Becker (1962, 1975), Mincer (1962, 1974), and Denison (1979), where they presented different ideas on the concepts and formation of human capital and also the role of human capital in the economy. Becker *et al.* (1994) defined human capital as embodied knowledge and skills that may enhance the technological progress as the economic development is apparently rely on the accumulation of human capital. OECD (2001) defined human capital in a broader way as human capital encompasses that "the knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being" (p.18).

The role of human capital in economic development could be perceived from macroeconomics and microeconomics perspectives. Macroeconomic perspective remarks that human capital is an important factor in sustaining economic growth and reducing poverty by enhancing labour productivity, facilitating technological progress and increasing returns to capital investment. Microeconomic perspective pointed out that higher education level increases the employment opportunity in the labour market, individual labour productivity and income capacity. Therefore, human capital is an important factor in the aggregate and firm production function.

2.6.1 Measures of Human Capital

There are various proxies used to measure human capital[12] in the empirical literature, such as literacy rates, school enrolment rate, average years of schooling, test scores and human development index.

Most of the earlier empirical studies tend to use literacy rates as the proxy to measure human capital (Romer, 1989; Azariadis & Drazen, 1990; Benhabib & Spiegel, 1994). UNESCO (1993, p. 24) defined literacy of individuals as who can "read or write a simple statement on his or her everyday life." However, literacy data ignore the skill and knowledge development of human capital at higher education level. Literacy rates might be a good proxy to measure human capital for countries with a lower level of education that has not reached the universal primary education (Judson, 2002).

School enrolment rate is another commonly used variable to measure human capital by earlier empirical studies (Barro, 1991; Mankiw et al., 1992; Levine *et al.*, 1992; Caselli et al., 1996). However, school enrolment rate does not incorporate the continuous investment in education and the dropout off education, grade repetition and graduates who do not enter the labour force. Thus, it may provide imprecise or misleading report when evaluating the relative precedence for educational investment (Psacharopoulos & Ariagada, 1986). In addition, the overstated enrolment statistics given by the developing countries reduce the reliability of the school enrolment rates.

[12] Oxley *et al.* (2008) discussed the methods in measuring human capital.

Average years of schooling data is another widely used proxy of human capital (Barro & Lee, 2001, 2010, 2013; de La Fuente & Domenech, 2006; Cohen & Soto, 2007; Lutz *et al.*, 2007). Average years of schooling capture the accumulation of investment in education and the years of formal education. However, average years of schooling may be subjected to error in cross-country analysis (Nehru *et al.*, 1995).

The education enrolment and attainment data provided by UNESCO are the common data set used to estimate the average years of schooling and this can be divided into three main estimation methods – the census/survey-based estimation method; the projection method and the perpetual inventory method[13].

2.7 Empirical Evidence on TFP in Asian Economies

Since the early 1990s, there has been a large and growing empirical literature on the contribution of TFP on Asia's economic growth. There are two different views on the forces that drive the rapid growth of Asian countries – accumulation and assimilation theories (Nelson and Pack, 1999). A partial list of these studies include Young (1995), Kim & Lau (1996), Bosworth and Collins (1996), Klenow and Rodriguez-Clare (1997), Kim (2001), Itawa et al. (2002), Lau and Park (2003), Park and Ryu (2006), Lee and Hong (2010), Park (2010) and Ahmed (2011).

Young (1992) measured the economic performance of Hong Kong and Singapore using the growth accounting exercise over the period 1965–1990. He found that TFP growth accounted about one-third of output growth in Hong Kong but zero for Singapore.

[13] Refer to Oxley *et al.* (2008) for details discussion on the estimation methods.

Based on Young's findings, Krugman (1994) published a seminal paper and argued that the rapid growth in NIEs is mainly contributed by capital accumulation which will inevitably slow down the economic growth as experienced by the Soviet Union in the 1950s[14].

Subsequently, Kim and Lau (1994) analysed the economic growth of the NIEs using two-input meta-production function method. Their findings showed that there is no technological progress for the NIEs during the period 1965–1990. Furthermore, Kim and Lau (1995) included explicitly human capital (measured by the average number of years of education of the working population) as an additional factor of production in the two-input meta-production function and obtained results that the NIEs and ASEAN economic growth is not contributed by technological progress. Their results showed that economic growth in the East Asian developing economies has been mainly determined by the growth of physical capital for the post-war period. Physical capital accounted between 65–85 percent of economic growth in these countries.

By using the growth accounting method, Collins and Bosworth (1996) showed that the East Asian economies have been driven by factor accumulation, while gains in TFP have been modest with an average of 1.1 percent per year over the period 1960–1994 which account for one-fourth of the region's growth in output per worker. However, they observed a more extensive TFP gains in the sub-period 1984–1994 for East Asia and South Asia regions, 1.6 percent and 1.5 percent per year, respectively.

[14] "[The] newly industrializing countries of Asia like the Soviet Union of the 1950s, have achieved rapid growth in large part through an astonishing mobilization of resources. Once one accounts for the role of rapidly growing inputs in these countries' growth, one finds little left to explain Asian growth, like that of the Soviet Union on ts high-growth era, seems to be driven by extraordinary growth in inputs like labor and capital rather than by gain in efficiency." (Krugman, 1994, p.70).

On the other hand, Klenow and Rodriguez-Clare (1997) found a very moderate contribution of human capital per worker to the output growth and TFP growth was the major factor in the growth of output per worker in Hong Kong, South Korea and Taiwan. Furthermore, based on the analysis on a sample of 98 countries, they found that almost 90 percent of the country variations in output per worker growth are due to variations in productivity growth over the period 1960–1985.

Meanwhile, Kim (2001) concluded that the forces of growth of East Asia seem to be shifted from accumulation-based to productivity-based over the period 1960–1999. However, factor accumulation is the main contributor to the output growth. TFP growth has an increasing trend over the period and its contribution was obviously increased since the 1980s. TFP growth accounted for a large part of economic growth in Singapore and Taiwan in the 1990s; 49% and 43%, respectively.

Moreover, Itawa et al. (2002) developed a non-parametric method to estimate the TFP growth of East Asian countries over the period 1960–1995. Their results support the assimilation hypothesis in which Hong Kong, South Korea, Singapore and Taiwan all have comparable high TFP growth of about 3.7 percent. The contribution of TFP growth accounted almost half of output growth whereas capital growth contribution only accounted around a quarter of the output growth in these countries.

In the meantime, Lau and Park (2003) revisited the issue regarding the role of technical progress in the East Asian countries using Meta-Production Function over the period 1965–1995. They found that physical capital is the main source of economic growth and no TFP growth in the East Asian NIEs and other Asian countries (ASEAN plus China) for the period before 1986 in which the physical capital accounted between 55 percent and 80 percent of economic growth as opposed to human capital which accounted only 3 percent, on average. Japan has significant technical progress which accounted for more than 45 percent of its economic growth. For the period 1986–1995, the contribution of Japan's technical progress to output growth (49.40%) was as much as the contribution of physical capital in the output growth (40.01%). The contribution of technical progress for the period 1986 –1995 still remains to zero for Asian countries except Japan.

On the other hand, a study by Park and Ryu (2006) showed that TFP is a primary source of growth in Hong Kong and Taiwan under the constant returns to scale growth accounting regression. The contribution of TFP in the economic growth for Hong Kong and Taiwan is 45.7 percent (for the period 1966–1995) and 42.9 percent (for the period 1953–1995), respectively, while, TFP contribution is just moderate in Korea (26.8%, for period 1960–1995) and Singapore (27.2%, for period 1964–1995) economic growth.

Using a growth accounting framework, Lee and Hong (2010) examined the contribution of the growth of factor inputs (capital, labour and education) and TFP to the growth of output for the 12 Asian economies for three decades (1981–2007) in terms of 10-year lags (e.g. 1981–1990; 1991–2000 and 2001–2007) and also for the entire period 1981–2007. They found that among the 12 economies, only China illustrated a high TFP growth contribution to GDP growth which grew by an average of 4.1 percent. Other economies in the sample showed that growth in physical capital contributed largely to the GDP growth except for the Philippines and Pakistan in which growth in the labour force were the main contributor to GDP growth. 10 out of the 12 Asian economies studied, the average growth in the physical capital stock was more than 5.85 percent per year for the period 1981–2007, which contributed more than 2.3 percentage points to the average GDP growth. The contribution of human capital or education to GDP growth seems to be limited. Based on these findings, Lee and Hong (2010) concluded that Asia region's economic development has in general been contributed by a significant physical capital accumulation growth.

Furthermore, Ahmed (2011) analysed the sources of growth for the ASEAN5 (Indonesia, Malaysia, the Philippines, Singapore and Thailand) plus three Asian economies (China, South Korea and Japan) for the period 1965–2006. His findings showed that, except for Japan, the contribution of TFP intensity growth was low. The contribution of capital intensity was highest during the period 1988–2006. However, the results indicated that the pattern of economic growth in South Korea is moving toward productivity driven.

2.8 Empirical Evidence on the Impact of Human Capital on TFP

2.8.1 Aggregate Human Capital and TFP

Various empirical studies intend to capture the notion of human capital in the growth regression by applying the conditional convergence concept predicted by the neoclassical growth model.

Based on his theoretical model, Romer (1990) estimated the impact of several variables like thr initial level of income, the investment rate government spending and literacy rate on a sample of 112 countries. He found that the literacy rate has a significant positive impact on economic growth. However, Romer's model empirical findings lack of robustness due to measurement error from omitted variables.

Barro (1991) observed that literacy rate across countries are not assessed consistently. Due to this problem, Barro (1991) used school enrollment rate which is more consistent across countries. Using primary and secondary school enrollment rates as proxies for human capital, Barro (1991) found that human capital level has a significant positive impact on per capita growth for a sample of 98 countries over the period 1960–1985. His results showed that a one percentage point increase in school enrollment rate will increase per capita growth by 0.3 percentage point.

Mankiw *et al.* (1992) analysed the role of human capital in the long-run steady state equilibrium and on the adjustment toward equilibrium by applying the augmented Solow-Swan neoclassical growth model. They found a significant positive relation for a sample of 98 countries over the period 1960–1985 and divided the sample into two subsamples i.e. least developed countries and OECD countries. Their findings showed that a one percentage point increase in secondary school enrollment increases the steady state level of output per capita by 0.7 percentage point but human capital impact is insignificant for OECD countries. However, the assumptions in their model that all countries have the same production function with a common rate of technological progress were criticised by other studies. Temple (2001) argued that this assumption is untenable and found that Mankiw's empirical results are highly sensitive to the measurement error.

Benhabib and Spiegel (1994) estimated human capital impact on growth using the standard growth accounting framework for a sample of 121 countries over the period 1965–1985. They found that human capital accumulation has an insignificant negative impact on per capita growth. This indicates that human capital accumulation is observed to lead to a negative economic growth even though the effect is statistically insignificant. Their empirical results were robust to the inclusion of several "ancillary independent variables" and to the use of alternative measures of human capital and inclusion of African region dummy variable. Benhabib and Spiegel argued that the negative human capital–growth impact findings were due to a conventional way of interpreting human capital as a factor of production. Then, they specified an alternative model by considering Nelson and Phelps (1966) specification to allow human capital in facilitating the speed of technological catch-up and found a positive impact of human capital on economic growth.

Moreover, Gemmel (1996) applied Mankiw *et al.* (1992) model by dividing human capital into primary, secondary and tertiary education. His findings showed that the impact of different education levels on growth differs across subsamples in which primary education has a greater impact on growth for the least developed countries, whilst secondary education has a significant impact on growth for intermediate developing countries and tertiary is important for the OECD countries. This might explain the insignificants of secondary enrollment in the findings of Mankiw *et al.* (1992).

Yet, the reliability of school enrolment rate has been questioned due to some shortcomings (refer to 2.5.1). Barro and Lee (1994) developed a data set on educational attainment (measured in average year of schooling) for a number of countries and employed it into their empirical study looking at the relationship between gender educational attainment and growth. They constructed the educational attainment data by separating the years of schooling using the number of years for a particular level of education.

Furthermore, Islam (1995) argued that country cross-section estimation may lead to omitted variable bias which may incorporate the effects of country-specific effects such as technological or institutional differences. Islam (1995) estimated Mankiw *et al.* (1995) growth model using a dynamic panel model with country specific fixed effect by applying Barro and Lee (1993) educational attainment data set. He found that human capital is negatively associated with economic growth. Using panel data, Caselli *et al.* (1996) estimated Barro and Lee (1994) model with generalized method of moments (GMM) estimation procedure and secondary school enrolment rate as a proxy for human capital also found a positive and significant impact of human capital on growth.

Applying cross-country panel data to the endogenous growth model for East Asia, McMahon (1998) estimated the effect of primary, secondary and higher education enrolment rate on growth based on a sample of 35 East Asian countries over the period 1965–1990. His finding showed that primary and secondary enrolments were significantly positively related to growth while higher education enrolment rate effect on growth was insignificant. This might be due to the high demand on the labour force at the secondary labour level in the production of manufacturing goods in the 1990s.

In addition, Bil and Klenow (2000) examined the causality relationship between education and economic growth. They found a weak relationship between schooling (proxy by school enrolment rate) and growth and observed a reverse causality correlation between human capital and economic growth. Thus, they commented that previous studies on the relationship between human capital and growth are subject to doubt.

Miller and Upadhyay (2000) estimated the determinants of TFP for panel data that covered developed and developing countries. Their empirical findings showed that the impact of human capital on TFP growth is positive for middle-income countries but has a negative impact for high-income countries. For low income countries, the effect of human capital on TFP growth alternates from negative to positive as the openness levels alternates from low to higher level. As a result, human capital investments will only have a significant contribution to growth for low-income countries with higher openness level.

Pritchett (2001) examined the relationship between human capital and growth rate of output per worker using cross section data over the period 1960-1985. He created a measure of educational capital using Mincer returns specification (Mincer, 1974) and found that the impact of educational capital growth on per worker growth and TFP growth are statistically negative.

Meanwhile, Krueger and Lindahl (2001) focused on the issue of measurement error that results estimated coefficients to bias downward. According to Krueger and Lindahl (2001), Benhabib and Spiegel (1994) findings were subject to low reliability of educational attainment data. They re-estimate Benhabib and Spiegel (1994) model using Barro and Lee (1993) educational attainment data set and found that education has only significant positive effect on growth for countries with the lowest level of education while countries with the middle and high level of education, education-growth effect is negative.

Similarly, Sunde and Vischer (2011) also addressed the inappropriate specification problem that result in contradictory findings. They focused on the misspecification of applying human capital in levels or logs in the empirical model that causes weak growth effects by considering two distinct measures – changes and level (initial) of human capital. The empirical results showed that the effects of human capital in level specification on growth are more robust than log specification because data for log changes and initial levels are highly correlated. Their results also suggested that the effect of human capital in levels on growth through measures, changes and initial levels results in consistent estimation. This implies that estimates with level specification for only one measure (changes or initial level) do not present total relevance of human capital for growth.

Self and Grabowski (2003) investigated the relationship between different education levels and economic growth in Japan for the period 1880–1989 by dividing it into pre-war (1880–1940) and post-war (1947–1989) period. They observed a causal impact of primary education on economic growth in both periods, but the causal impact of secondary and tertiary education on economic growth was only observed in the post-war period.

Furthermore, Ada and Acaroglu (2014) examined growth and human capital relationship by applying Mankiw *et al.* (1992) model in a panel sample of 15 MENA (Middle East and North Africa) countries over the period 1990 to 2011. They used three proxies for education primary completion rate, pupil teacher ratio and public education expenditure. Education primary completion rate and pupil teacher ratio showed significant positive impact on growth. The impact of education spending on growth is insignificant for the MENA countries. This implies that better higher education quality/ environment is important in enhancing economic growth.

2.8.2 Gender Human Capital and TFP

Greater economic gains contributed by educated female as compared to educated male have become a well-known argument (Schultz, 2002). Female education which contributes to growth does not only increase female labour participation rate but also increases the productivity of female labour force. However, there is still not much empirical evidence to show on the impact of gender-separate on growth and the results are mixed.

The issue on gender human capital on economic development was primarily emphasized by Benavot (1989) with argument that the issue of the impact of gender human capital on economics has been neglected. Benavot examined the effect of gender differences in education on economic growth for a panel sample of 96 countries over the period 1960–1985. He tested female and male education separately in the regression to avoid the multicollinearity problem that was often ignored by researchers. His findings showed that female and male primary and secondary enrollment rates effects on growth is significantly positive with primary education effects are greater on growth than secondary education for both genders.

A popular and frequently cited empirical study on gender differences education on growth is a seminal paper written by Barro and Lee (1994). They examined female and male education effects on growth for two time periods (1965–75 and 1975–1985) using cross-country data of 116 countries. Their findings showed that growth is positively associated with male education, while growth is negatively associated to female education. They explained this “puzzling” result by giving explanation that the great gender schooling gap is a motion of backwardness, hence, low female educational attainment implies greater backwardness that generates higher growth rate through the convergence mechanism. The puzzling findings caused Barro and Lee (1994) empirical results been questioned on the aspect of reliability.

The “puzzling” explanation by Barro and Lee has been commented by Stokey (1994) that the insignificant impact of female education on growth was with another justification that the significant female variable on growth was due to dummies variable in the regression. Seemingly, the female variable was acted as geographic region or ethic group acted as dummies that treat educate woem differently from men. Stokey (1994) also remarked that there was a high correlated relationship between female and male education, thus by omitting the female education variables from the regression are likely to reduce the value of male education. This causes doubt on Barro and Lee (1994) statistical significance. Stokey (1994) also considered the collinearity problem of female and male education variable in Barro and Lee’s model and suggested to remove the female education variable from the model. She found insignificant coefficient of female education if regional dummy are considered in the regression estimation.

Using Barro and Lee (1994) method, Barro and Sala-i-Martin (1997) examined human capital effects on growth using female and male secondary education levels by adding the changes of male and female secondary and higher schooling variables. They found that male secondary and male higher education effects on growth are positively significant whereas female secondary and female higher education effects are negatively insignificant. However, the changes of male and female secondary and higher schooling variables are insignificant in the equation. .

In contrast, Caselli *et al.* (1996) argued that the negative sign of the coefficient of female education in the growth model may likely be due to the inconsistent estimation methods, thus, the estimated coefficients are unreliable. The inconsistency methods failed to cater the country-specific effects which results in omitted variable bias and simultaneity bias. They solved the problems by using the GMM estimator to estimate Mankiw *et al.* (1992) growth model. Using panel data of 97 countries for the period 1960–1985 with the GMM estimation, Caselli *et al.* (1996)[15] found that female education positively affects economic growth while male education impact is negative. Nonetheless, there is no theory on the incorrect sign of male and female human capital coefficients in the growth theory.

Similarly, Forbes (1998) also believed that the inconsistent or mixed findings on female education and growth was due to measurement error and omitted variable bias. Therefore, Forbes (1998) applied different panel data estimation methods (i.e. fixed effects, random effects and GMM estimator) to control the country-specific effects. Based on a sample of 45 countries for the period 1965–1996, Forbes (1998) findings support Caselli *et al.* (1996) results on the positive effects of female education on growth in the regression. Yamarik and Ghosh (2004) used system GMM estimator also found a significant positive female education-growth effect.

Additionally, Lorgelly and Oven (1999) also reexamined Barro and Lee model by identifying influential observations and outliers. They found that the four NIEs are the influential observations that caused the “puzzling” findings in Barro and Lee empirical study. Yet, the exclusion of these influential observations

[15] Caselli *et al.* (1996) questioning Barro and Lee (1994) findings by arguing the inconsistency of female and male education which could be due to the omitted variable problems caused by the country-specific effects and the simultaneous relation between education and economic growth variables. They solve these problems by applying GMM estimation.

produced statistically insignificant relationship between male and female education and growth. Thus, they concluded that Barro and Lee's results are sensitive to the observations in the sample and their backwardness argument on the "puzzling" empirical results is unpersuasive and weak.

The separate effects of gender education on growth has been further examined by Dollar and Gatti (1999) by measuring male and female education as the percentage of completed secondary school for male and female population for a panel of 127 countries for period 1975–1990 by applying fixed effects model. Their findings showed a marginally significant negative impact of male education and positive impact of female education on growth.

Correspondingly, Barro (2001) reexamined the relationship between education and economic growth in a panel of 100 countries over the period 1960–1995. His findings showed that the effect of male secondary and higher education on growth is positive while female secondary and higher education has a negative impact on growth. Barro argued that it is due to the gender inequality traditions that limit the efficient exploitation of educated female in the labour force.

On the other hand, Kalaitzidakis *et al.* (2001) addressed the nonlinear education-growth relation using panel data estimation. They found that the relationship between female education and growth are positive at low schooling levels but are negative at higher schooling levels, while the relationship between male education and growth are significantly positive at higher schooling levels.

A recent study by Hassan and Cooray (2013) investigated the effects of female and male education on economic growth for a panel of 15 Asian countries for the period 1970–2009. They used enrollment ratio as the measures for human capital and found that female and male primary, secondary and tertiary education have significant impact on growth. They claimed that the significant impact of female and male tertiary education on technology transfer could be explained by the increasing labour demand on human capital with higher education level (tertiary education) in the transformation process of developing Asian countries' industrialization policy.

2.9 Technology-Adopting Role of Human Capital and TFP Growth

As mentioned earlier, Romer (1990) argued that human capital is the main input factor to the research and development sector, which resulted in the development of new products or ideas that underlie technological change and also increased the stock of knowledge. Most of the population of the developing countries is large and this may increase the number of their labour force. However, the low quality of labour force may not be sufficient to support the diffusion of technology. Scherer (1999) advocated the important role of human capital as a significant input factor in advancing technological level of a country.

Accordingly, Nelson (2005) categorised the role of human capital in economic growth into two main schools of thought – accumulation and assimilation theories. Accumulation theories treat human capital as a key factor of production on labour productivity, while assimilation theories explore the impact of the human capital level on the dual dimensions of TFP growth: innovation and knowledge externalities of technology transfer from technology frontier to lagging countries. Human capital represents the ability and efficiency of people to assimilate and accumulate knowledge and apply it in the production process effectively. Thus, human capital can be referred to as knowledge and basic skills that mainly obtained through the educational system.

In a model with multiple convergence clubs, Papageorgiou (2002) argued that backward (poor) countries that are not sufficiently close to the technological frontier are not able to absorb advanced technologies. He coined the notion of "contiguous knowledge[16]" in his model and concluded that

"it is not possible for countries that are far away from the frontier to take advantage of existing technologies and grow rapidly. In contrast, developing countries that are closer to the frontier possess sufficient know-how that allows them to adopt existing innovations and grow fast, thus converging to the income level of the technology leader. Contiguous knowledge is implicitly a threshold argument. That is, countries below a technology-gap threshold are not capable of adopting existing technologies whereas countries above this technology-gap threshold find it easier to adopt existing technologies and grow rapidly. Therefore as argued above, the predictions of the model are consistent with economic miracles as well as economic disasters (p. 364)".

2.9.1 Human Capital and TFP Gap

Based on Nelson and Phelps' (1966) theoretical model, Benhabib and Spiegel (1994) developed a model which conjectures that human capital affects total factor productivity in dual dimensions. First, following Nelson and Phelps' model, human capital has an indirect effect on productivity growth through the adoption of technology developed elsewhere. Second, following Romer's model, the direct

[16] The notion of "contiguous knowledge" states the idea that knowledge spreads out a certain distance.

impact of human capital on productivity growth is via the innovation of new technology. Using a cross-country analysis with a sample of 78 developed and developing countries over the period 1965–1985 and measuring human capital as the average number of years of schooling in the labour force, Benhabib and Spiegel (1994) found that human capital is an important factor in facilitating technology transfer process. In their theoretical model, the effect of international technology facilitated by human capital is measured by the interaction between the gap of the output of the leading country and the output of the domestic country, and the domestic country's human capital. Their results showed that a one percent increase in the average level of human capital is related to an average increase in per capita GDP growth of 12.2 percent to 16.7 percent. According to their finding, for the whole sample, the contribution of human capital to productivity growth is due to its contribution in absorbing and adopting technology developed abroad. They also estimated their model by dividing the entire sample into two samples – developed and developing countries and claimed that human capital contributes to productivity growth primarily via the adoption of foreign technology for less developed countries while human capital contributes to productivity growth primarily via innovation of new technology in developed countries.

Moreover, Basu and Weil (1998) proposed a logistic model of diffusion which specifies that technology diffusion only happens in those countries in which the technology levels are close to the home country. This implies that no technology diffusion from advanced to laggard countries occurs if their technology gaps are sufficiently large. Subsequently, Benhabib and Spiegel (2005) modified their model in 1994 and proposed the logistic model of technology diffusion by applying Basu and Weil idea. They found that the human capital shows a significant impact in determining TFP growth rates through its influence on the rate of technological catch-up and innovation. In addition, their empirical results support the logistic specification of technology diffusion model for a sample of cross-section countries over the period 1960–1995. They also found that 22 out of 27 countries whose human capital level is less than the critical level may experience slow economic growth in the future.

At the micro level, Doms *et al.* (1997) showed that plants with a higher share of high skilled and high educated workers have a greater number of applications of advanced technologies. Foster & Rosenzweig (1996) acknowledged that, as a result of the Green Revolution phase in India, the profitability of the educated farmer is increasing by adopting new varieties of high-yield seed and chemical fertilizer. These findings are consistent with Nelson and Phelps' hypothesis that educated worker is important in facilitating technology transfer.

Acemoglu (2000) found that technical change has been skill-biased over the past 60 years. According to him, higher education level impact on TFP growth was critical because skilled or educated workers are a significant capacity of a country to perform technological innovation and also adopt and efficiently apply foreign technology.

Correspondingly, Abreu *et al.* (2004) estimated the standard Nelson–Phelps model of technology diffusion using the average years of schooling as a measure of human capital for a cross-section of 73 countries over the period 1960–2000. The coefficient of average years of schooling has a direct significantly positive impact on TFP growth in which a one percent increase in the average years of schooling caused a 0.5 percent percent increase in the TFP growth over the period 1960–2000. Their findings indicated that the level and growth rate of human capital have a positive direct impact on TFP growth. Using a panel data set of 13 developing countries for the period of 1982–1998, Bascavusoglu (2004) also supported that human capital variable has a significantly positive effect on TFP growth.

Based on a panel of 21 industrial countries and 82 developing countries over the period 1970–1995, Kwark and Shyn (2006) found that human capital with the secondary school enrolment rate has a positive and significant relationship with TFP growth for all the specifications with the elasticities ranging from 0.06 to 0.08. Thus, they concluded that human capital stock is a dominant factor in the adoption of foreign R&D stocks.

Di Liberto *et al.* (2008) studied the relationship between TFP dynamics and human capital stocks for 73 countries over the period 1960–2003. They found that initial human capital stocks are positively correlated with TFP growth rate. By decomposing human capital into three different levels of education (primary, secondary and tertiary education), only the primary year of schooling has significant impact on TFP growth. In the subsample of high-tech countries (countries with initial level of relative TFP greater than 0.3) only tertiary education shows positive effects on TFP growth while for low-tech countries, only secondary schooling shows a significant and positive impact on TFP growth.

Vandenbussche *et al.* (2006) proposed a theoretical model in which technological progress consists of adoption (imitation) and innovation of new technologies which require application by different types of human capital (skilled and unskilled). The effect of different types of human capital on TFP growth depends on a country's development stage which is proxy by the distance to the technology frontier (Vandenbussche *et al.*, 2006). With the assumption that innovation activities requires human capital which are relatively high skilled intensive rather than imitation activities, they tested the model on 19 OECD countries over the period 1960–2000 and found that skilled labour (tertiary level education) has higher enhancing impact on TFP growth for countries whose distance to the technological frontier are closer.

Aghion *et al.* (2009) extended Vandenbussche *et al.*'s (2006) model into a multi-sectoral analysis on US regional panel data. They found that there were positive effects of exogenous shocks to research-type education on TFP growth for those states with distance closer to the technology frontier.

Meanwhile, Ha *et al.* (2009) developed a theoretical model based on the assumption that country with the closer distance closer to the technology frontier tends to be dependent on technology creation than adoption and have higher investment in basic research than in development and thus higher investment in skilled labour than unskilled labour. Their empirical analyses on a panel data of Asian developed countries (Japan, South Korea and Taiwan) showed that the closer the distance to the technology frontier, the higher the impact of basic research (highly skilled labour) on economic growth.

Subsequently, Danquah *et al.* (2010) adopted Vandenbussche *et al.* (2006) model to examine the effect of human capital composition on TFP growth, technical progress (innovation) and technical efficiency (adoption of technology) in a panel sample of 19 Sub-Saharan countries over the period 1960–2003. They found that primary and secondary educations are positively related to technical efficiency but the effects decrease with proximity to the frontier. Tertiary education is positively related to technical progress and TFP growth and the effect increases with proximity to the frontier.

Using Vandenbussche *et al.* (2006) model, Ang *et al.* (2011) investigated whether the contribution of human capital to TFP growth depends on the composition of human capital and proximity to the technology frontier on 82 countries by grouping these countries into high, medium and low income. They used three different educational data sets (Barro and Lee, 2001; Cohen and Soto, 2007 and IIASA-VID, 2013[17]) and classified the educational level into primary, secondary and tertiary education. Their empirical evidence showed that primary and secondary school education affect TFP growth positively for the full sample estimation and only a weak positive TFP growth effect from tertiary education. In the subsample of high income and middle income countries, the estimate results showed that tertiary education has a significant positive effect on TFP growth while primary and secondary education effect on TFP growth are insignificant. This implies that for those countries that are closer to the technology frontier, higher education is important in accelerating their TFP growth. For low income countries, the effect of any educational level on TFP growth is insignificant. Thus, they concluded that education is not an influential variable for TFP for low income countries due to the low quality of teaching and poor attendance rate of students.

Ang *et al.* (2011) empirical results seem to match the argument of Aghion and Durlauf (2007) that policy implications related to the relationship between human capital and growth should take into consideration the effect of various

[17] IIASA-VIS human capital dataset is provided by International Institute for Applied Systems Analysis (IIASA) and the Vienna Institute of Demography (VID).

compositions of human capital on TFP growth which depends on the development stage of a country. Aghion and Durlauf (2007) claimed that lower education (primary and secondary education) is important for Europe when technological distance was farther away from US as imitation is main source of TFP growth, but higher education (tertiary education) become more important in order to foster innovation as technological distance closer to US.

Again, applying Vandenbussche *et al.* (2006) model, Danquah and Quattara (2014) examined the impact of human capital to TFP growth, innovation and technology transfer for a sample of 19 Sub Sahara African countries for the period of 1960–2003. The coefficients of TFP gap is negative and statistically significant related to TFP growth as predicted by the model. On overall, human capital has insignificant impact on overall TFP growth. By decomposing TFP growth into efficiency and technical changes, they found that human capital has a significant positive impact on efficiency change (technology adaption) and insignificant impact on technical change (innovation). Their findings were consistent with Vandenbussche *et al.* (2006) argument that the unskilled human capital is significant in facilitating technology transfer for countries farther away from technological frontier as the stock of human capital in Sub Sahara African countries are relatively low.

Papakonstantinou (2014) studied the impact of high-skilled (tertiary education) human capital on TFP growth by considering the distance from the technological frontier on two different samples – 19 OECD countries for the period 1960–2000 and 109 countries for the period 1950–2000 using Instrumental Variables. In this model, tertiary education impact on TFP growth was U-shaped in which is greater for countries farther away from technological frontier than decreases as countries move closer to technological frontier but from a point onwards increase again.

2.9.2 Human Capital and FDI

Borensztein *et al.* (1998) developed a model that focuses on FDI as a channel of technology transfer from developed to developing countries in a sample of 69 developing countries for the period 1970–1989. In their model, per capita GDP growth of a country relates to FDI inflows, human capital, and an interaction term between FDI and human capital as the absorptive capacity of the country that affect economic growth of a country. Measuring FDI inflows as FDI from the OECD countries to the sample countries, they assumed that FDI inflows represent foreign technology based on the argument that inflows of FDI from these countries may likely deliver new technological knowledge to the developing countries. They found that the direct effect of FDI inflows on economic growth is ambiguous but the effect of interactive term between FDI and human capital or the absorptive capacity is positive and significant. In their study, the magnitude of the coefficients shows that countries could only benefited from FDI inflows if their human capital level is higher than 0.52 years of secondary schooling.

Similarly, Xu (2000) studied the effect of technology transfer through FDI on productivity in a sample of 40 countries which consists of 20 developed and 20 developing countries over the period of 1966 to 1994. Technology transfer through FDI used by Xu's (2000) was between the US Multinational Enterprises (MNEs) and their foreign affiliates in other countries which is measured by the ratio of royalties and license fees pay by the foreign affiliates. His findings showed that the direct impact of technology transfer through US MNEs on productivity growth was significant in the sample of developed countries but not for developing countries.

Xu (2000) also estimated impact of different threshold levels of human capital needed for a country to benefit from the technology transfer of US MNE. He found that technology transfer through FDI has a positive effect on productivity growth only for countries that have reached a minimum threshold of human capital level of 1.9 years of secondary schooling in the population over 25 years old. This threshold level is higher than the threshold level of 0.52 years of secondary schooling found by Borenzstein *et al.* (1998). Xu (2000) argued that the presence of MNEs increase productivity gains to developing countries was due to the contribution of the MNEs on the market structure rather than from technology transfer. He proved this hypothesis on the sample of developing countries that the relationship between the direct impacts of MNEs investment on productivity is positively significant but the impact of technology transfer on productivity growth is insignificant.

Moreover, Lee (2001) adopted Borensztein *et al.* (1998) model to examine the role of human capital in the technology diffusion process through FDI and imports of machinery and transportation equipment in a cross-country regression for a sample of 57 countries for the period 1970–1995. His model expressed the technological absorptive capacity as an interaction term between FDI and human capital and import of machinery and transportation equipment. The findings showed that the interaction term of FDI and human capital has significant positive effects on TFP growth. The effect of the interaction term between import of machinery and transportation and human capital also provided significant positive effect on TFP growth, showing that human capital is an important factor in facilitating the absorption of global technologies effectively.

In the same way, Campos and Kinoshita (2002) studied the impact of FDI as technology transfer variable on economic growth in 25 transition economies over the period 1990–1998 using a model developed by Borenzstein *et al.* (1998). Their findings showed a significant positive impact of FDI on growth in transition economies, but the impact of growth is not dependent on the host country's human capital level.

2.9.3 Human Capital and Openness

Miller and Upadhyay (2000) developed a model in which TFP is associated with trade openness, human capital and an interaction term between trade openness and human capital as absorptive capacity of technology transfer. They believed that trade openness will encouraging technology transfer across countries. By using a sample of 83 developed and developing countries between 1960 and 1989, they found that effects of human capital on TFP growth is negative in high-income countries and positive in middle-income countries, while for low-income countries, human capital effect on TFP growth changes from negative to positive as the country increase level of openness from a low to a higher one. Their findings also showed that trade openness and the interaction between trade openness and human capital has a positively significant impact on TFP growth for entire sample. Based on these results, they concluded that higher trade openness induces technology transfer and countries with higher human capital level will gain greater technology transfer and productivity growth.

Similarly, Mayer (2001) emphasised the significant role of human capital to a country's productivity growth as a determinant of its capacity to carry out innovation and facilitate technology transfer through imported technology from abroad. Based on a sample of 53 developing countries for the period 1970–1990, Mayer (2001) found a statistically significant positive effect of the interaction term between human capital and machinery imports on productivity, implying that human capital is an important factor in adopting foreign technology and country's productivity. Savvides and Zachariadis (2003) asserted that human capital has a significant positive effect on the growth rate of TFP manufacturing sector in low-income and middle-income countries.

2.9.4 Human Capital and R&D

On the other hand, Coe *et al.* (1997) argued that the technology transfer process of developing countries is highly depending on foreign R&D spillovers from industrial countries through imports of capital goods. Thus, he examined the effect of foreign R&D on economic growth for 77 developing countries from period 1971–1990. Based on his argument, Coe *et al.* (1997) examined a linear empirical equation that relates TFP to foreign R&D, the degree of trade openness and education level and including two interaction terms: foreign R&D and trade, and R&D and education level. Their results implied that the effects of foreign R&D spillovers on TFP growth are substantial for developing countries.

Meanwhile, Engelbrecht (1997) extended Coe *et al.* (1997) model by adding human capital stock as mechanism in the technology transfer process with an interaction term between human capital and output gap. Their estimation results on a pooled data for 21 countries over the period 1971–1965 support the importance of human capital in the domestic innovation process and TFP catch-up using cointegration regression..

Furthermore, Engelbrecht (2002) analysed and compared the two major approaches to the modelling of human capital in TFP growth regressions: the Coe *et al.* and the Nelson and Phelps approach, in the context of developing country models with international knowledge spillovers. He examined the models for a pooled of 61 countries over the period 1971–1985 using fixed effects estimator. The empirical results seem to support the Nelson and Phelps approach on the role of human capital in the absorption of international knowledge transfer. He also showed that the level of secondary education has a significant positive effect on TFP growth when it is interacted with a GDP gap variable.

In addition, Griffith *et al.* (2004) developed a model based on Benhabib and Spiegel's (1994) technology diffusion specification in such a way that TFP growth depends on the innovation of new technology, on technological distance from technological frontier that interact with absorptive capacity and on technological distance from technological frontier the country (technology gap). In Griffith *et al*. (2004) model, the technology transfer term is referred to as the productivity gap between the country in a particular industry and the most productive country in that industry.

Using a panel of manufacturing industries of a sample of 12 OECD countries over the period 1974–1990, Griffith *et al.* (2004) tested the hypothesis by applying the absorptive capacity in terms of R&D intensity and human capital. In their study, R&D intensity and human capital was measured by the percentage of R&D expenditure in output and the percentage of tertiary education of total population, respectively. They found that R&D and human capital affect productivity growth in dual ways: through innovation and technology transfer from abroad. Their result showed that a one percent increase in R&D investment will increase the productivity growth between 0.69% and 1.05%. They found that most of the R&D's and human capital contribution to productivity growth is achieved through innovation for those countries closer to the technology frontier while through technology transfer for those countries farther from the technology frontier. The magnitude of human capital impact on TFP growth through technology transfer was large in countries farther away from the technology frontier.

Similarly, Crispolti and Marconi (2005) studied the impact of foreign R&D expenditures (by TRIAD[18] members) on TFP levels in a panel of 45 developing countries for the period 1980–2000 using FMOLS estimation model. In their study, they emphasized the role of human capital in the technology transfer process in the developing countries and found that at a certain level of foreign R&D capital stock, countries that attain higher average years of schooling experiences greater technology transfer.

[18] TRIAD is a cluster of countries which include the NAFTA, the European Union and the industrialized Eastern Asia (Japan, Taiwan, South Korea, Hong Kong and Singapore).

Kneller (2005) studied the extent of absorptive capacity in the technology transfer process in terms of human capital and R&D using a panel of manufacturing industries from 12 OECD countries over the period 1972 to 1992. In contrast to Griffith et al. (2003), Kneller's study focused on the level of TFP instead of TFP growth. In this study, absorptive capacity is measured using an R&D proxy by ratio of R&D to GDP and human capital proxy by the average years of schooling in the population aged 25 and above. Kneller (2005) found empirical evidence consistent with the hypothesis that human capital as technological absorptive capacity is significant in facilitating technology transfer. His finding showed that the role of R&D is significant in increasing innovation but its role in technology transfer process is significant only for less R&D-intensive OECD countries. Assuming the United States as the leading country in most industries and using the ratio of the productivity of a country to the productivity of the U.S., Kneller estimated whether the productivity ratio of human capital of the countries in the sample had the same levels of human capital in the US. He found that the effect on productivity ratio is high for countries that have human capital levels that are close to US, while countries that have human capital levels that are far from the US, the effect on productivity is low.

Since most of the developing countries are technological followers, human capital may contribute to the absorption of foreign technology by adopting and applying them to local conditions and for alternative uses. Therefore, policies that enhance education, facilitate the adoption of new technologies and eliminate barriers to technology diffusion are important in closing the gap between rich and poor countries. A brief summary of the absorptive-capacity-based studies is shown in Table 2.1.

2.10 Conclusion

In the growth literature, human capital is theoretically a crucial contributes to economic and productivity growth. Different theoretical growth models are constructed to incorporate the impact of human capital on economic growth. In Neo classical growth theory, human capital is treated as a factor of production as physical capital and it indicates that human capital accumulation (changes in education) affect the long-run economic growth rate. Whereas, the endogenous growth theory relate the role of human capital and technological progress in enhancing economic growth and it indicates that both changes and initial level of education affect the long-run economic growth. However, the empirical findings on aggregate and gender human capital and growth relation are inconclusive over the last two decades. This is because the literature is subject to methodological and conceptual issues such as inadequacy proxy of human capital, estimation methods and reserve causality. The methodology of endogenous theory also empahises the impact of human capital on technological catch-up by improving the innovation and technology transfer absorptive capacity in enhancing the TFP growth of a country. Commonly, the empirical results support the positive impact of human capital on TFP growth. For different level of human capital, higher human capital enhances TFP growth through innovation for advanced countries and lower human capital facilitates technology transfer for developing countries.

Table 2.1
Studies on Absorptive Capacity and Technology Transfer (based on Aggregate Data)

Study	**Sample**	**Absorptive Capacity**	**Foreign Technology**	**Effect of Absorptive Capacity on Technology Transfer**
Benhabib & Spiegel (1994)	Cross Section of 78 developed and developing countries	Human capital (educational attainment of labour force)	Productivity gap between the country and the leading country	Positive and significant. More important for developing countries than for developed countries.
Engelbrcht (1997)	Cross section of 21 countries for period of 1971–1985	Human capital (average year of schooling)	Relative gap between real per capita GDP and real US per capita GDP	Positive and signifcant
Borenztein, Gregorio & Lee (1998)	A panel of 69 developing countries over the period 1970–1989	Human capital (proxy by the average male secondary school attainment in the population over 25 years old)	FDI inflows from OECD countries to developing countries in the sample	Positive and significant.
Miller & Upadhyay (2000)	A panel of 83 developed and developing countries from 1960–1989	Human capital (proxy by the average number of years of schooling for adult population)	Ratio of exports to GDP	Positive and significant.

Table 2.1 (Continued)

Engelbrecht (2002)	Pooled data of 77 developing countries over 1971–1990	Average years of schooling, average years of primary and secondary schooling, average years of female schooling, average years of female primary and secondary schooling	Foreign R&D capital and TFP gap	Primary schooling/foreign R&D capital interaction term is significant but not for secondary schooling/ foreign R&D capital interaction term. Female primary schooling/ foreign R&D capital interaction term is significant. Average year of schooling/TFP gap interaction term is positively significant on TFP growth. Female schooling/TFP gap interaction term also significant on TFP growth.
Griffith, Van Reenan & Redding (2003)	A panel of manufacturing industries in 12 OECD countries over the period 1974–1990	R&D expenditures/ sales Human capital (proxy by percentage of total population that attained tertiary education)	Productivity gap between the country and the leading country	Positive and significant for R&D and human capital and both effects on productivity are more important for countries farther from the technology frontier.
Abreu *et al.* (2004)	Cross-section of 73 countries over the period 1960–2000	Human capital (average years of schooling)	Productivity gap between the country and the leading country	Positive impact on TFP growth and technology catch-up

Table 2.1 (Continued)

Benhabib & Spiegel (2005)	Cross-section of 85 countries over the period 1960–1995	Human capital (average years of schooling)	Productivity gap between the country and the leading country	Positive and significant.
Crispolti & Marconi (2005)	A panel of 45 developing countries for the period of 1980–2000	Human capital (average years of schooling)	R&D trade, R&D FDI	Positive and significant
Kneller (2005)	A panel of manufacturing industries in 12 OECD countries for the period of 1972–1992	R&D expenditures/ sales Human capital (proxy by years of schooling in the population age 25 and above)	Productivity of the leading country	Positive and significant for human capital. Positive but insignificant for R&D, except for countries with low technology intensive countries.
Vandenbussche *et al.* (2006)	19 OECD countries over the period 1960–2000	Human capital composition – average years of primary, secondary and tertiary schooling	Productivity gap between the country and the leading country	Tertiary education and its interaction term have positive and significant impact on TFP growth.
Kwark & Shyu (2006)	21 industrial countries and 82 developing countries for the period of 1970–1995	Human capital (secondary enrolment rate)	TFP growth	Positive and significant

Table 2.1 (Continued)

Ahmed & Suardi (2007)	Cross section of 28 Sub-Saharan countries over the period 1971–2000	Human capital (proxy by the secondary years of schooling)	Technology gap	Positive and significant.
Di Liberto *et al.* (2008)	73 countries over the period 1960–2003 (divide into 2 subsamples – high-tech and low-tech)	Human capital composition – average years of primary, secondary and tertiary schooling	TFP growth	For high-tech countries, tertiary education have significant impact on TFP growth while for low-tech countries, secondary countries have significant impact on TFP growth
Islam (2009)	A panel of 55 countries (23 OECD and 32 developing countries) over the period 1970–2004	R&D expenditure Patent application Patent granted Human capital (proxy by secondary enrolment ratio)	Productivity gap between the country and the leading country	Positive and significant.
Danquah *et al.* (2010)	A panel of 19 Sub-Saharan countries over the period 1960–2003	Human capital composition – average years of primary, secondary and tertiary schooling	Productivity gap between the country and the leading country	The effects of primary and secondary education decrease with productivity to the frontier. The effects of tertiary education decrease with productivity to the frontier

Table 2.1 (Continued)

Ang *et al.* (2011)	A panel of 82 countries (32 high income, 37 middle income and 72 low income countries) over period 1970–2004	Human capital composition – average years of primary, secondary and tertiary schooling (also in term of female and male human composition levels)	Productivity gap between the country and the leading country	Tertiary education and its interaction term have a positively significant effect on TFP growth for subsample high income and middle income countries. Human capital composition and the interaction terms have no impact on TFP growth for subsample low income countries.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology used in the study that includes the empirical models, hypothesis development, and data measurement and estimation methods. Estimation methods applied in the present study are pooled ordinary least square (OLS) and static linear panel data model (fixed effects model (FEM) and random effects model (REM).

3.2 The Empirical Model

3.2.1 Growth Accounting Method: The Decomposition Equation

The TFP growth estimates of developing Asian economies for the period 1970–2009 are based on the standard Solow growth accounting method as discussed in Section 2.4.1. In brief, growth accounting is a method to analyse the relative contribution of factor inputs and the level of technological progress which is also called TFP to the economic growth. The analysis of TFP growth contribution provides the basis fundamental and essential information for a country in the policy planning to enhance output and productivity growth.

As show in Equation (2.1), the variation in output is decomposed into the contributions of capital, labour and a residual measure of the contribution of TFP. Thus, TFP is estimated as written in Equation (2.2): $A = TFP = \frac{Y}{K^{\alpha}(L)^{1-\alpha}}$. As mentioned earlier, the parameter α is the capital share of output[19] which indicates the share of income which belongs to capital stock while $(1 - \alpha)$ is the labour share of

[19] Gollin (2002) concluded that the adjusted measures of factor shares are approximately the same across industrial and developing countries.

output[20], and it is assumed $\alpha = 0.30$ as by Klenow nd Rodriguez-Clare (1997) and Ang *et al.* (2011). This is consistent with Gollin (2002) calculation on the share of labour and application of a constant factor share across countries. According to Gollin (2002) estimation, the labour shares $(1-\alpha)$ for Asian countries[21] are between 0.65 and 0.85.

In order to estimate the TFP as in Equation (2.2), physical capital stock is constructed by using the perpetual inventory method as used in Caselli (1996, 2005) whereby the capital accumulation equation is specified as follows[22]:

$$K_t = I_t + (1-\delta)K_{i,t-1} \qquad (3.1)$$

where, K is the amount of capital stock, δ is the depreciation rate which was assumed at five % by Bosworth & Collins (2003)[23], and I is total investment.

To obtain capital stock data series, initial capital stock is estimated by the following equation[24]:

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[20] Under the assumption of competitive labour market, the labour share of output which can be calculated from the labour compensation data. However, , the actual labour shares are difficult to calculate for developing countries due to unavailable of labour compensation data. Thus, a concession is achieved by assuming a common constant value for the labour shares across all countries (Park, 2010).

[21] The labour share calculated by Gollin (2002) for India, Japan, Korea, Philippines and Vietnam are 0.828, 0.692, 0.697, 0.661 and 0.802, respectively. Gollin (2002) make an adjustment on the naïve employee compensation share that takes into consideration of self-employment income in developing countries.

[22] Most studies commonly follow the method of Harberger (1978) in calculating initial capital stock, which assumed that the economy is in a steady state level at the initial stage of development, thus, the capital growth rate is same with the output growth rate $\left(\frac{dK}{K} = \frac{dY}{Y}\right)$. Since, $\frac{(K_t - K_{t-1})}{K_{t-1}} = \left(\frac{I_t}{K_{t-1}}\right) - \delta$, then $\left(\frac{I_t}{K_{t-1}}\right) - \delta = g$, where K is capital stock, I is investment, δ is the depreciation rate and g is the growth rate of output or investment.

[23] This study uses $\delta = 0.05$ is not arbitrary but is followed the estimation found in various studies, for example Cororaton (2002) for the Philippines, Felipe (1997) for a sample country in East Asia and etc.

[24] $\frac{I_0}{g_{ss}+\delta}$ is the expression for the capital stock in the steady state of the Solow model (Caselli, 1996, 2005).

$$K_0 = \frac{I_0}{g_{ss}+\delta} \quad (3.2)$$

where I_0 is the initial real investment, g_{ss} is the average growth rate of real investment over the period 1970–2009.

The TFP growth rate can be calculated by taking first differential of the log of TFP:

$$\Delta \ln A = \Delta \ln(Y) - \alpha(\Delta \ln K) - (1-\alpha)\Delta \ln L \quad (3.3)$$

where Y is the real GDP, K is physical capital stock, L is labour force.

3.2.2 Total Factor Productivity, Technology Transfer and Absorptive Capacity

The empirical model that is employed in this study is as proposed by Benhabib and Spiegel (2005). Their empirical specification is a technology catch-up model using human capital proxy as a measure of the technology absorptive capacity of a country. According to Nelson and Phelps (1966) and Benhabib and Spiegel (1996, 2005), human capital is not only intended as a factor of production but also as a factor enhancing technological flows across countries where its role would be that of increasing the rate of technology diffusion. Besides the aggregate human capital level effect on TFP growth (as by Benhabib and Spiegel, 1994, 2005), this study also examines the impact of gender-separate human capital on TFP growth in two aspects, which are the aggregate and composition level. Differences in gender educational levels may have different impact on TFP growth directly and indirectly depending on the relative distance to the technological frontier.

In the nested specification Equation (2.11), the logistic technology diffusion model expressed by Benhabib and Spiegel (2005) is in linear version $(s = 1)$. In addition, follows Griffith et al. (2004), this study considers direct technology transfer (or autonomous technology transfer) as a source of productivity growth for countries behind the technological frontier. As TFP accounts for a wide range of the income variations between developed and developing countries, technology gap is an important factor in explaining income disparities across countries. According to Griffith *et al.* (2004), autonomous technology transfer indicates that countries farther away from the technology frontier will have higher TFP growth rate, ceteris paribus. Besides through technology transfer process, lagging countries are also likely to enhance productivity by depending on institutional and government policies that may have great influence on the autonomous technology transfer. Thus, this study adds the direct technology transfer into the linear logistic technology diffusion model specification. The empirical models of this study are developed as follows:

3.2.2.1 Level Effect of Aggregate Human Capital

In the light of Nelson and Phelps (1966) technology catch-up theory, Benhabib and Spiegel (1994, 2005) relates the impact of the stock of human capital on TFP growth in two dimensions, namely, direct impact of human capital through innovation and indirect impact of human capital through its ability in facilitating technology transfer. Thus, the empirical model is as follows:

$$\Delta A_{it} = \beta_0 + \beta_1 HC_{it} + \beta_3 \frac{A_i}{A_t^{max}} + \beta_2 HC_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \beta_4\, FDI_{it} + \beta_5\, OPENK_{it} + \varepsilon_{it} \tag{3.4}$$

where $\beta_1 = (g + c)$, $\beta_2 = c$, ΔA_{it} is TFP growth rate of country i, $\frac{A_{it}}{A_t^{max}}$ indicates the technological gap or referred to as autonomous technology transfer which is the distance to technological frontier of relative TFP gap between the sample countries and the technological frontier country the US, HC_{it} represents human capital which is measure as the average years of total schooling for total population aged 15 years and above (proxy for aggregate human capital level), FDI_{it} denotes the percentage of foreign direct investment inflows to GDP, $OPENK_{it}$ is the openness ratio to GDP at 2005 constant prices and ε_{it} is the error term. TFP growth is a common empirical proxy for technological progress as applied by most researchers (e.g. Mankiw *et al.*, 1992; Caselli *et al.*, 1996; Benhabib & Spiegel, 1996, 2005; Vandenbussche *et al.*, 2006 and Ang *et al.*, 2011). The TFP growth is measured as "Solow residual" and is calculated by adopting the Solow Neo-classical growth accounting model over the period 1970–2009 (as presented in Section 2.4.1).

As stated by Benhabib and Spiegel (2005), $\beta_1 HC_{it}$ represents the impact of human capital on TFP growth through innovation, the interaction term between human capital and TFP gap (distance to frontier), $\beta_2 HC_{it}\left[\frac{A_{it}}{A_t^{max}}\right]$ represents the absorptive capacity based on human capital. By increasing the educational attainment, lagging countries can increase their ability to absorb foreign technology, and thus, foster the speed of technology transfer. While, $\beta_3 \frac{A_{it}}{A_t^{max}}$ represents the autonomous technology transfer in which technology transfer occurs independently of human capital. TFP gap has been used by Griffith *et al.* (2004), Vandenbussche *et al.* (2006) and Ang *et al.* (2011) to capture autonomous technology transfer. Autonomous technology transfer indicates that, other things remain constant;

countries farther away from the technological frontier may gain faster TFP growth and ε_{it} is the error term. The subscript $'i'$ denotes a particular country and subscript $'t'$ indicates a particular time period.

3.2.2.2 Level Effect of Gender Human Capital

Gender human capital enhances TFP growth through technology transfer. Considering that female human capital has significant ability in facilitating technology transfer, the growth enhancing effect of female human capital increases for countries that farther away from technological frontier. Thus, the empirical models for gender human capital are as follows:

$$\Delta A_{it} = \gamma_0 + \gamma_1 FHC_{it} + \gamma_2 \frac{A_{it}}{A_t^{max}} + \gamma_3 FHC_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \gamma_4\, FDI_{it} + \gamma_5\, OPENK_{it} + \varepsilon_{it} \quad (3.5)$$

$$\Delta A_{it} = \varphi_0 + \varphi_1 MHC_{it} + \varphi_2 \frac{A_{it}}{A_t^{max}} + \varphi_3 MHC_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \varphi_4\, FDI_{it} + \varphi_5\, OPENK_{it} + \varepsilon_{it} \quad (3.6)$$

where $\Delta A_i(t)$ is TFP growth rate of country i, $\frac{A_{it}}{A_t^{max}}$ indicates the technological gap or referred to as autonomous technology transfer which is the distance to technological frontier of relative TFP gap between the sample countries and the frontier country the US, FHC_{it} and MHC_{it} represents human capital which is measure as the average years of total schooling for female population and male aged 15 years and above, respectively (proxy for gender human capital level); and FDI denotes the percentage of foreign direct investment inflows to GDP, $OPENK$ is the openness ratio to GDP at 2005 constant prices and ε_{it} is the error term. The subscript $'i'$ denotes a particular country and subscript $'t'$ indicates a particular time period.

3.2.2.3 Gender Composition Effect of Human Capital

Vandenbussche *et al.* (2006) investigate the impact of human capital on TFP growth through innovation and technology transfer. Effective technology transfer requires higher educated skilled workers for developing countries (Hanushek & Woesmann, 2013). The empirical models are as follows:

$$\Delta A_{it} = \psi_0 + \psi_1 FPRI_{it} + \psi_2 \frac{A_{it}}{A_t^{max}} + \psi_3 FPRI_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \psi_4\, FDI_{it} + \psi_5\, OPENK_{it} + \varepsilon_{it} \quad (3.7)$$

$$\Delta A_{it} = \omega_0 + \omega_1 FSEC_{it} + \omega_2 \frac{A_{it}}{A_t^{max}} + \omega_3 FSEC_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \omega_4\, FDI_{it} + \omega_5\, OPENK_{it} + \varepsilon_{it} \quad (3.8)$$

$$\Delta A_{it} = \xi_0 + \xi_1 FTER_{it} + \xi_2 \frac{A_{it}}{A_t^{max}} + \xi_3 FTER_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \xi_4\, FDI_{it} + \xi_5\, OPENK_{it} + \varepsilon_{it} \quad (3.9)$$

$$\Delta A_{it} = \tau_0 + \tau_1 MPRI_{it} + \tau_2 \frac{A_{it}}{A_t^{max}} + \tau_3 MPRI_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \tau_4\, FDI_{it} + \tau_5\, OPENK_{it} + \varepsilon_{it} \quad (3.10)$$

$$\Delta A_{it} = \vartheta_0 + \vartheta_1 MSEC_{it} + \vartheta_2 \frac{A_{it}}{A_t^{max}} + \vartheta_3 MSEC_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \vartheta_4\, FDI_{it} + \vartheta_5\, OPENK_{it} + \varepsilon_{it} \quad (3.11)$$

$$\Delta A_{it} = \varrho_0 + \varrho_1 MTER_{it} + \varrho_2 \frac{A_{it}}{A_t^{max}} + \varrho_3 MTER_{it}\left[\frac{A_{it}}{A_t^{max}}\right] + \varrho_4 FDI_{it} + \varrho_5\, OPENK_{it} + \varepsilon_{it} \quad (3.12)$$

where $\Delta A_i(t)$ is TFP growth rate of country i, $\frac{A_{it}}{A_t^{max}}$ indicates the technological gap or referred to as autonomous technology transfer which is the distance to technological frontier of relative TFP gap between the sample countries and the frontier country the US, $FPRI_{it}, FSEC_{it}, FTER_{it}$ present female primary, secondary and tertiary average years of schooling for population aged 15 years and above, respectively and $MPRI_{it}, MSEC_{it}, MTER_{it}$ denote male primary, secondary and tertiary average years of schooling for population aged 15 years and above, respectively, and FDI_{it} denotes the percentage of foreign direct investment inflows to GDP, $OPENK_{it}$ is the openness ratio to GDP at 2005 constant prices, and ε_{it} is the error term. The subscript $'i'$ denotes a particular country and subscript $'t'$ indicates a particular time period.

3.3 Hypotheses Development

The following hypotheses will be examined for a sample of 12 Asian developing countries over the period 1970–2009.

Hypothesis 1: The share of TFP growth in the growth of GDP. The relative contribution of TFP growth is considered as the technological progress that explains the growth in output over time, while holding other input levels fixed. It accounts for an increasingly large share of output growth as countries develop further.

Hypothesis 2: TFP gap is significantly negative related to TFP growth. As argued by convergence literature that other things being constant, for countries those farther away from the technological frontier are likely having higher TFP growth. It also referred as autonomous technology transfer.

Hypothesis 3: Human capital has a significant positive impact on TFP growth. Higher average level of educational attainment may have more impact in promoting higher TFP growth directly (through innovation activities).

Hypothesis 4: Human capital based absorptive capacity has a significant negative effect on TFP growth. Since technology transfer requires adequate human capital ability to absorb foreign technology efficiently, high educated or skilled human capital may have more impact in enhancing TFP growth for countries farther away from the technological frontier and stimulating technology transfer process.

3.4 Data Measurement

This study uses a panel data approach to examine Asian developing countries' TFP growth over the period 1970–2009. Penn World Tables 7.1 (PWT 7.1) compiled by Heston, Summer and Aten (2012) is employed in calculating the TFP growth. Average years of schooling data as proxy for human capital were obtained from Barro and Lee (2013) educational attainment data set[25] on the average years of schooling for population aged 15 years and above. The data are provided quinquennially with initial value over each five-year period. The macroeconomic control variables data is extracted from UNCTAD (United Nations Conference on Trade and Development) online dataset and PWT 7.1. The definition and sources of the variables are listed in Appendix A3 Table A1. The data consist of eight separate five-year non-overlapping periods to adjust the effect of the long-term economic policies and reforms: i.e. 1970–1974, 1975–1979, 1980–1984, 1985–1989, 1990–1994, 1995–1999, 2000–2004 and 2005–2009. Due to the cyclical effects, five-year intervals are less sensitive to temporary shocks that related to business cycles. Observations are in terms of five-year differences for variable TFP growth, the five-year average for variables FDI and trade openness and initial value over

[25] The new data set of educational attainment by Barro and Lee (2010) addressed the problems commended by De la Fuente and Someneh (2006) and Cohen and Soto (2007) by "…reduce measurement error by using observations in 5-year age interval for the previous or subsequent 5-year periods as in Cohen and Soto (2007). … also construct new estimates of (a) survival/ mortality rates by age and by education; and (b) completion ratios by educational attainment and by age group. These measures help improve accuracy of the backward- and forward-estimation procedure… new procedure have resolved [time-series profiles of educational attainment] (p.184, 185)."

each five-year period for variables human capital and TFP gap that applied in the empirical model.

The sample size comprises 12 Asian developing countries. The selection of countries was due to the constraint of the data limitation. The countries involved are listed in the Appendix A4 Table A2.

TFP growth, ΔA: The variables used in the TFP growth calculation are real GDP (Y), real investment (I) and number of workers (L). The derivation of these variables is using the data from PWT 7.1 that measured based on five-year differences. PWT data provides purchasing power parity and national income account converted to real International United States dollar that provides the results of international comparison.

Y is measured as the real GDP in international dollar which computed as rgdpwok*L. Lack of data on number of labour for the sample countries, this study follows Caselli (1996, 2005) calculation to obtain data on number of workers. Number of workers, L, is calculated as (rgdpch*pop)/rgdpwok where rgdpwok is the real GDP per worker adjusted for purchasing power parity at 2005 constant price that based on chain index, rgdpch is the real GDP per capita with the chain method at 2005 constant price and *pop* is the number of population. According to PWT 7.1 definition, workforce is the working age population aged between 15 and 65.

Data on K are not published and it requires some calculation. This study employs permanent inventory method (as presented in Section 3.2.1) that consistent with neo-classical model and time series data (United Nation, 2007). To compute K, I is needed as indicated in Equations (3.1) and (3.2). In this study, I is calculated as rgdpl*pop*ki which was used by Caselli (2005) and Islam (2009), where rgdpl is the real income per capita with the Laspeyers method at 2005 constant price and *ki* is the investment share of rgdpl. All notations used follow the original form stated by PWT 7.1.

Human capital: Education has been commonly referred as measure for human capital by researcher (e.g. Barro, 1991; Mankiw *et al.*, 1992; Barro & Lee, 2001, Vandenbussche *et al.*, 2006 and etc). This study employs average years of schooling which has been commonly used by researchers as proxy for human capital as it captures the accumulation of investment in education and the years of formal education (Barro & Lee, 2001, 2010, 2013) which reflect the current productive human capital stock (Chen & Dahlman, 2004). Barro and Lee (2013) educational attainment dataset is employed as it covers a large number of countries over the period 1950–2010 and their estimation is using consistent census data, heterogeneity in mortality rates and completion rates across age group and educational level. The level of human capital used in the study is proxied by the average years of total schooling (HC), average years of total schooling for female population (FHC) and average years of total schooling for male population (MHC) aged 15 and above. This study also uses the composition of gender educational attainment data which is measured by female and male primary, secondary and tertiary years of schooling aged 15 and above (i.e. $FPRI$, $FSEC$, $FTER$, $MPRI$, $MSEC$, and $MTER$).

TFP gap, $\left[\frac{A_i}{A^{max}}\right]$: It represents the distance to technological frontier which is measured by the relative TFP difference between the sample countries (A_i) and the

US (A^{max}). As the technological leader and the major trading partner of the developing countries in the world, the USA technology is considered as the world frontier technology. Autonomous technology transfer indicates that, other things remain constant; countries farther away from the technological frontier may gain faster TFP growth.

Human capital based absorptive capacity, $HC \times \left[\frac{A}{A^{max}}\right]$: It is measured by the interaction between human capital, HC, and the TFP gap, $\left[\frac{A}{A^{max}}\right]$. This interaction term implies that higher human capital level has greater absorptive ability to enhance TFP growth for those countries lagging behind the technological frontier through technology transfer (Nelson & Phelps, 1966).

Control variables: This study included two control variables, (i) percentage of foreign direct investment inflows to GDP (FDI) obtained from UNCTAD (United Nations Conference on Trade and Development) interactive database and (ii) openness ratio to gross domestic product at 2005 constant prices ($OPENK$) obtained from PWT 7.1.

3.5 Estimation Techniques

3.5.1 Orthogonalizing Normality

The interaction term or referred to as product term (XY) is highly correlated with the original explanatory variables (X and Y). The collinearity problem will cause the estimation to be unstable and imprecise (increase the standard errors of regression coeffficients). Orthogonalizing or residual centering is an approach proposed by Lance (1980) to solve the collinearity problem in the regression analysis that involves interaction term. Orthogonalizing is a two-stage ordinary least square procedure whereby an interaction term is regressed onto its two original variables. The residual of this regression is used to represent as a new variable of the interaction term. This new orthogonalized interaction term has mean zero and correlates zero with its original variables.

3.5.2 Panel Data Analysis

Generally panel data analysis allows one to exploit both the time-series variation and cross-sectional heterogeneity of the tested variables. The nature of this panel data is balanced as it incorporates time series and cross-sectional deviations.

3.5.2.1 Pooled Ordinary Least Square Regression

The basic panel model in Equation (3.4) is rewritten to get Equation (3.13):

$$\Delta A_{it} = \beta_0 + \beta_1 (HC_{it}) + \beta_2 (HC_{it}) \left[\frac{A_{it}}{A_t^{max}}\right] + \beta_3 \left[\frac{A_{it}}{A_t^{max}}\right]_{it} + \beta_4 \, FDI_{it} + \beta_5 \, OPENK_{it} + \varepsilon_{it} \quad (3.13)$$

which show pooled OLS relationship between the TFP growth and the human capital based absorptive capacity. The pooled OLS model does not capture the different of unobservable individual specific effects whereby the coefficients of intercept and slope are restricted to be the same across countries. The error term, ε_i is likely to contain unobserved individual specific effects that are correlated with other observed independent variables. Thus, pooled OLS regression may result in heterogeneity bias which may cause the estimates of independent variables to be biased and inconsistent. In order to accommodate such heterogeneity, there is a need to control those unobserved time-invariant individual specific effects by including individual specific fixed effects in the error term ε_{it} to take into account the unobservable factors such as macroeconomic fluctuations that might have significant impact on TFP growth in the sample. Two types of panel data estimators, fixed effects and random effects estimators have been developed to handle the systematic tendency of ε_{it} to be higher for some countries than for others (country-specific effects).

3.5.2.2 The Fixed Effects Model

The fixed effects estimator is used if the individual specific component is correlated with respect to the independent variables. The FEM is a linear regression which introduces dummy variables that allow the intercept to vary for each country.

In general, the fixed effects model can be written as:

$$y_{it} = \alpha_i + x'_{it}\beta + \varepsilon_{it} \qquad \varepsilon_{it} \sim IID(0, {\sigma^2}_{\varepsilon}) \qquad (3.14)$$

where x'_{it} denotes a vector of independent variables, α_i represents the individual specific effects that varies among individuals but constant over time (the differences may be due to the special feature of each individual) , β is the vector of coefficients on independent variables and all x_{it} are assumed to be independent of all ε_{it}. If α_i is correlated with the independent variables of x_{it} and it is part of constant intercept. When the covariance between the individual specific effect and any independent variables is not zero, the OLS estimators are consistent and unbiased. The parameters can be estimated by OLS by applying the dummy variable technique to allow for the intercept to vary between individuals. Using dummies to estimate the FEM is also known as the least square dummy variable (LSDV) model.

In the context of the analysis, the FEM is written as follows:

$$\Delta A_{it} = \beta_0 + \beta_1[HC_{it}] + \beta_2[HC_{it}]\left[\frac{A_{it}}{A_t^{max}}\right] + \beta_3\left[\frac{A_{it}}{A_t^{max}}\right]_{it} + \beta_4\,FDI_{it} + \beta_5\,OPENK_{it} + \alpha_i + \varepsilon_{it} \quad (3.15)$$

where $\alpha_i$is country-specific effects and ε_{it} is the error term. In applying the LSDV technique, α_i is proxied by country dummies. If α_i is correlated with the independent variables, $x_{it,}$ then the OLS estimator from Equation (3.26) is unbiased and consistent. However, FEM or LSDV modelling may lose a substantial number of degrees of freedom and cannot identify the effects of applicable explanatory variables that do not change over time (Kmenta, 1986).

3.5.2.3 The Random Effects Model

Instead of considering individual-country specify effect (α_i) as fixed and not correlated with other explanatory variables, random effects model (REM) assumes that the intercepts are drawn from a common distribution, and the error term consists of two components: an error term unique to each observation and constant over time (α_i) and an error term representing the extent to which the intercept of a given cross-sectional unit varies from the overall intercepts(ε_{it}). This means that individuals have a common mean value for the intercept and the individual differences are reflected in the error term.

In general, the REM can be written as:

$$y_{it} = a + x'_{it}\beta + (\alpha_i + \varepsilon_{it}) \quad (3.16)$$

$$\varepsilon_{it} \sim IID(0, \sigma^2{}_{\varepsilon});\ \theta_i \sim IID(0, \sigma^2{}_{\alpha})$$

$$E(\varepsilon_i \alpha_{it}) = 0 \qquad E(\varepsilon_i \varepsilon_j) = 0 \qquad (i \neq j)$$

$$E(\alpha_{it}\alpha_{is}) = E(\alpha_{it}\alpha_{jt}) = E(\alpha_{it}\alpha_{js}) = 0 \qquad (i \neq j : t \neq s)$$

where the composite error term $v_{it} = \alpha_i + \varepsilon_{it}$ comprise two components – an individual-specific component and the error term that is assumed to be uncorrelated over time. If α_i is assumed to be random variable that α_i is uncorrelated with the independent variables of x_{it}. The OLS estimator for α and β from Equation (3.15) is unbiased and consistent. This model is called random effects model. The covariance matrix of the random effects estimator is ${\sigma^2}_\varepsilon[\sum_{t=1}^{T}\sum_{i=1}^{N}(x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)' + \theta T\ \sum_{i=1}^{N}(x_{it} - \bar{x}_i)(x_{it} - \bar{x}_i)']^{-1}$ where $\alpha = \frac{{\sigma^2}_\varepsilon}{{\sigma^2}_\varepsilon + T{\sigma^2}_u}$. In the REM, the composite error term v_{it} is serially correlated, thereby $corr(v_{it}, v_{is}) = \sigma_u^2/(\sigma_\alpha^2 + \sigma_\varepsilon^2), t \neq s$ where $\sigma_\alpha^2 = var(\alpha_i)$ and $\sigma_\varepsilon^2 = var(\varepsilon_{it})$. This will result in inconsistent estimators in the random effects model. To overcome this problem, the estimation by the Generalised Least Square (GLS) estimator is required in the estimation of REM.

In the context of our analysis, the REM is written as follows:

$$\Delta A_{it} = \beta_0 + \beta_1[HC_{it}] + \beta_2[HC_{it}]\left[\frac{A_{it}}{A_t^{max}}\right] + \beta_3\left[\frac{A_{it}}{A_t^{max}}\right]_{it} + \beta_4\, FDI_{it} + \beta_5\, OPENK_{it} + \nu it \qquad (3.17)$$

where $\nu_{it} = \theta_i + \varepsilon_{it}$; θ_i is the individual-specific random element and β_0 is the overall intercept.

In the FEM, the intercept value is fixed across cross-sectional units; in the REM, individuals have a common mean value for the intercept and the individual differences are reflected in the error term.

3.5.2.4 Hausman Test: Fixed Effects versus Random Effects Model

The Hausman (1978) test is applied to determine the appropriateness of REM or FEM. The Hausman specification test is used to check and compare the efficiency and consistency of two estimators by determining the correlation of individual-specific effects and independent variables in the model. Under null hypothesis, independent variables and individual specific effects are uncorrelated. By comparing two estimators, one is efficient and consistent under the null hypothesis, but inconsistent under the alternative hypothesis; and the other is consistent under both null and alternative hypothesis. The hypotheses of Hausman test are stated as follows:

H_o: the coefficients estimated by the efficient random effects estimator are the same as the ones estimated by the consistent fixed effects estimator, and

H_a: the coefficients estimated by the efficient random effects estimator are not the same as the ones estimated by the consistent fixed effects estimator.

If null hypothesis fails to be rejected, both fixed effects and random effects estimators are consistent (as their variances are close to each other) but only random effects estimator is efficient, thus random effects model is more appropriate. On the other hand, if the null hypothesis is rejected, only fixed effects estimator is consistent (as their variance are starkly different from one another), thus FEM is more appropriate.

3.6 Conclusion

This chapter presents and discusses the research methodology of this study. It presents the empirical models used in the study to derive TFP growth using standard growth accounting model and examines the impact of human capital absorptive capacity in the technology transfer process by applying Logistic Technology Diffusion Model. The issues of data measurement, hypothesis development and estimation methods used in the study also describe in this chapter.

CHAPTER FOUR

RESULTS AND DATA ANALYSIS

4.1 Introduction

Differences in TFP growth are major source explaining the variations in income across countries. This study estimates and analyses the TFP growth of developing Asian countries for the past four decades (1970–2009). As technology followers, developing Asian countries are highly dependent on foreign technologies developed abroad, thus, technology transfer is important in explaining the productivity growth in developing Asian countries. The effectiveness of technology transfer is determined by the absorptive capacity which depends on the literacy level of workforce of a country. This study also examines the impact of human capital at different levels of education by genders in enhancing TFP growth through dual dimensions: ability of innovation and absorptive capacity of foreign technologies developed elsewhere. This chapter presents and discusses the results of data analysis and estimation to keep to the objectives of study as underlined in Chapter 1.

4.2 TFP Growth

As explained earlier, the key issue regarding the developing Asian countries' growth has been the relative importance of the contribution of TFP growth to the region's economic growth. This section provides cross-country TFP growth estimation of 12 developing Asian countries for the period of 1970–2009. The TFP growth rate of developing Asia is estimated using Equation (3.3).

Figure 4.1 shows the contributions of the input factors and TFP growth to the growth of output (GDP) and GDP growth rate for the 12 developing Asian countries. The average annual growth rate of TFP growth for developing Asian countries ranged from –0.4 percent to 3.7 percent. Among the sample of 12 countries, China has achieved highest growth of TFP growth over the period 1970–2009 in which grew by an average of 3.7 percent. This estimated result is consistent with Holz's (2006) and Bosworth and Collins (2008) estimation of China's TFP growth 3.8 percent, respectively. Sri Lanka, Thailand and Vietnam also performed a relatively high growth in TFP, more than 2.0 percent during the same period. These findings seem to be consistent with the TFP estimations by Asian Productivity Organization (APO, 2012) for Sri Lanka, Thailand and Vietnam were 1.9 percent, 1.6 percent and 2.1 percent, respectively, over the period 1970–2011. India, Indonesia, Malaysia and Pakistan also achieved average TFP growth of nearly 2 percent in the period 1970–2009[26]. The TFP growth in Papua New Guinea and Philippines were less than one percent on average, while Bangladesh and Nepal had a TFP growth of negative over the whole observation period.

In terms of the relative contribution of TFP growth to GDP growth, TFP was a main factor in driving the GDP growth of developing Asian countries over the past four decades. As observed from Figure 4.1, developing Asian countries; except Bangladesh, Nepal, Papua New Guinea and Philippines, TFP growth contribution accounted or almost one-third or more of the GDP growth rate over the 40–year period. Among them, the contribution of TFP to GDP growth was more than half in China (52.77%) and Sri Lanka (51.38%). Over the past four decades, TFP growth for

[26] TFP estimation by APO (2012) for India, Indonesia, Malaysia and Pakistan (at the range of 1.4–0..5 percent over the period 1970–2011) were lower than the study estimation.

Bangladesh and Nepal is –10.64 percent and –12.42 percent, respectively. This negative TFP growth was attributed to shortages of skilled human capital for Bangladesh (Rao & Hassan, 2009) and inefficient usage of resources for Nepal (Bajracharya, 2000)**.**

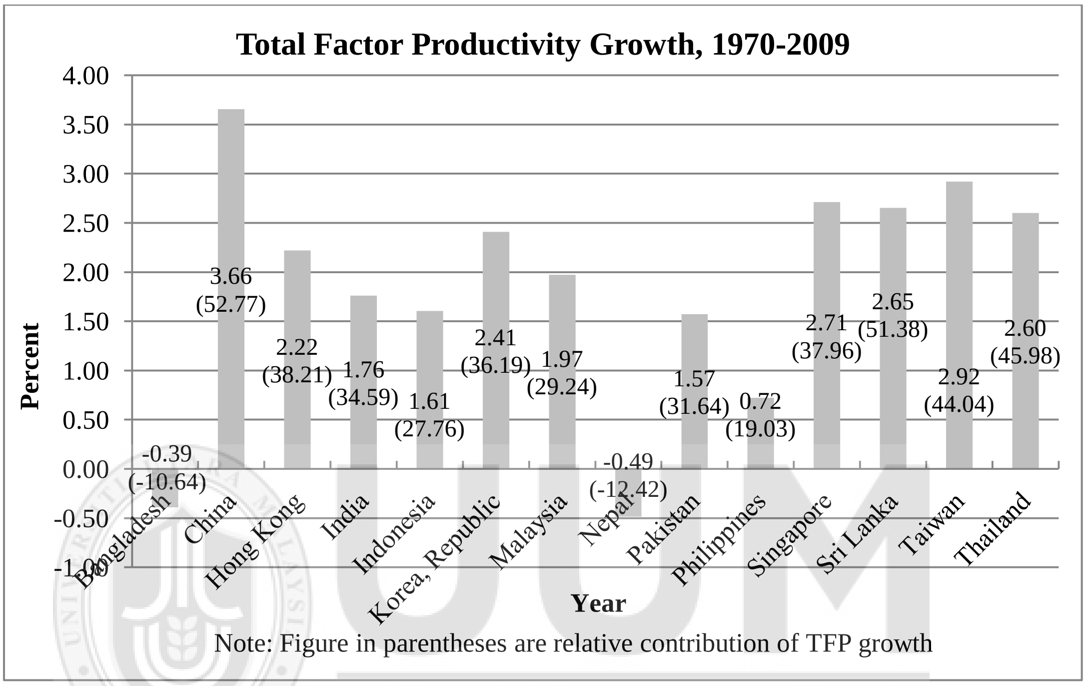

Figure 4.1
Average Annual TFP Growth, 1970 –2009

The estimation results show that there is an extensive TFP gains in developing Asian countries. This is consistent with Sarel (1996), Klenow and Rodriguez-Clare (1997)[27] and Hsieh (2002) findings that TFP growth (technological progress) was an important contributor to the rapid and sustained economic growth in Asian countries. As the contribution of factor inputs might change over time, this study discusses briefly on the decadal outlook of the TFP growth contributions for the developing Asian countries.

[27] Klenow and Rodriguez-Clare (1997) compared and explained their estimation results with Young (1994) of the four Asia NIEs. The differential results were due to the usage of different data set and the capital share. This study follows Klenow and Rodriguez-Clare (1997) by using Summer-Heston data and capital share of 0.3.

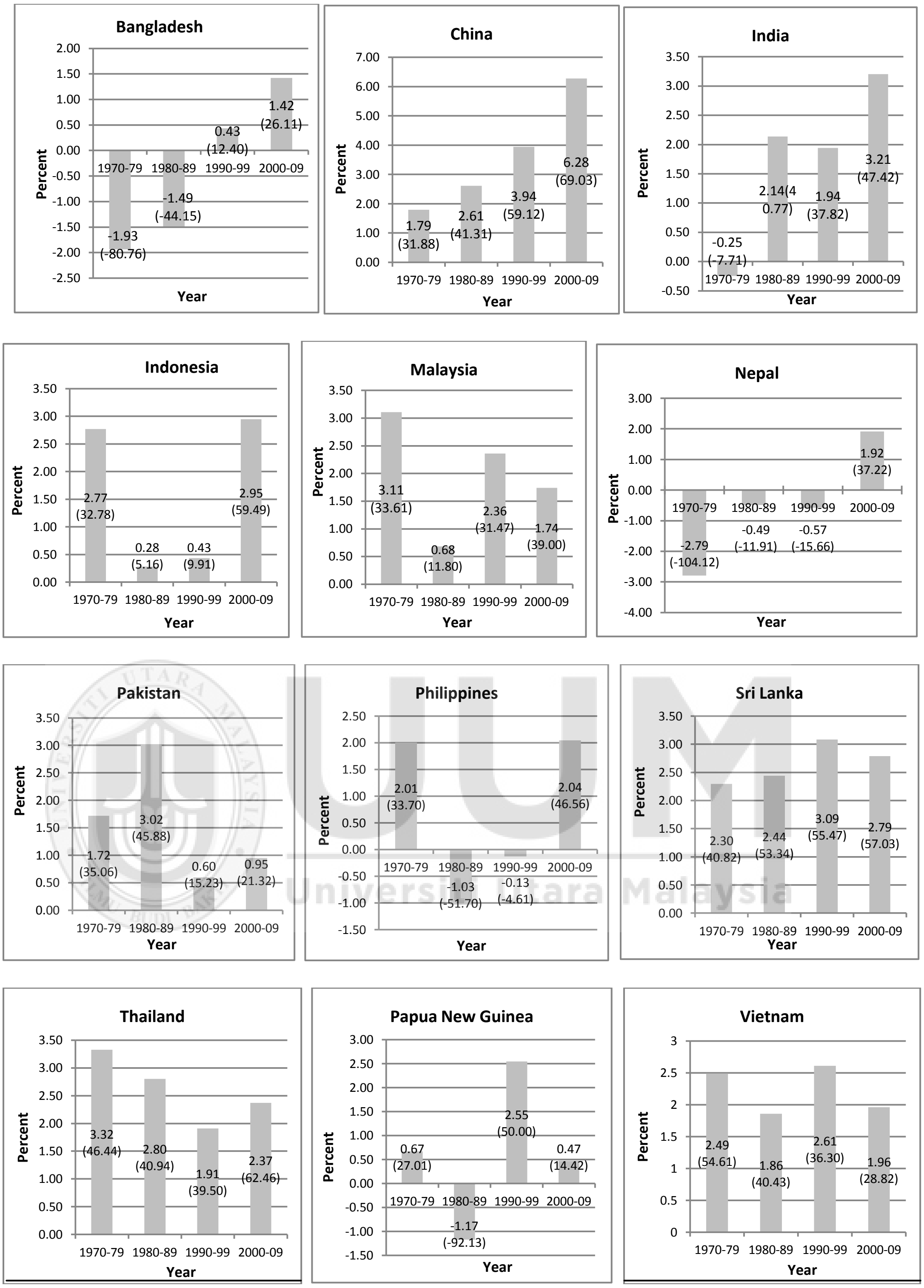

Figure 4.2
Individual Countries' Average Annual TFP Growth, 1970–2009

Figure 4.2 shows decade-average TFP growth estimates for the periods 1970–1979, 1980–1989, 1990–1999 and 2000–2009 of the selected 12 developing Asian countries. Throughout the four decades (1970–2009), the TFP growth rates have fluctuated over time and these were partly attributed to temporary internal and external economic shocks and business cycles (APO, 2012).

However, the estimates of China TFP growth were robustly positive and increasing all over the four decades. India showed a strong improvement in the contribution of TFP growth after the 1970's which was partly reflected by a recovery of the weak economic condition from the unstable political environment in the 1970's (Collins, 2007). The TFP growth in Bangladesh and Nepal has steadily improved from negative to positive TFP growth for the past four decades. Sri Lanka has a consistent pattern of TFP growth at 2.0 percent–3.0 percent (relative contributions of TFP were more than 40% as shows in Figure 4.2) throughout the period 1970–2009. Thailand and Vietnam also showed a stable TFP growth at the range of 1.91 persent–3.32 percent and 2.0 percent–2.73 percent over the four decades, respectively. While, the Philippines's TFP growth had declined sharply in the 1980s and bound back in the 2000 with TFP growth at 2.04 precent (contribution of 46% to the GDP growth).

The contribution of TFP growth to GDP growth was significant in the developing Asian countries over the four decades. Specifically, the contribution of TFP was robust for most of the developing Asian countries in the 2000's whereby its contribution to GDP was more than 40 percent on average (as illustrated in Figure 4.2). This is consistent with Park (2010) [28] and APO (2012) estimations that the

[28] Park's (2010) estimation decadal results show in Appendix A5 (Table A3). He used capital share of 0.4 in his estimation of TFP growth on Asian economies for 1970–2007.

contribution of TFP growth increased significantly in the developing Asian countries in the 2000's. Park (2010) estimated the TFP of Asian countries for the period 1970–2007 using the growth accounting model and found that the contribution of TFP growth to GDP is the lowest in four Asian NIEs and four ASEAN countries for the period 1970–2000; however, it seems to have improved extensively after year the 2000. India, Pakistan and Vietnam had a relatively low TFP contribution to GDP growth while China had a strong positive TFP growth throughout the whole period. His findings showed that the primary source of developing Asian countries' growth is shifting from the accumulation of physical capital for the pre-2000 period to the TFP growth in the post-2000 period which is consistent with the paradigm shift of the region's development from a low-income country to a growingly middle-income country.

The estimated results signify that Asian developing countries have moved toward to the productivity based growth (Park & Park, 2010) and catch-up with the more developed countries. The increasing pattern of TFP growth indicates that developing Asian countries attained TFP gains by adopting foreign technologies which may lead them catching-up to the technological frontier.

4.3 Descriptive Statistics

Table 4.1 reports the descriptive statistic of the variables used in this study for the sample of 12 developing Asian countries over the period 1970–2009.

Table 4.1
Descriptive Statistics, 1970-2009

Variable	Mean	Standard Deviation	Minimum	Maximum
ΔA_{it}	0.049	0.085	-0.156	0.289
$TFP\ gap_{it}$	0.165	0.074	0.062	0.430
HC_{it}	4.594	2.255	0.500	10.310
FHC_{it}	3.962	2.483	0.120	10.200
MHC_{it}	5.250	2.102	0.870	10.520
$FPRI_{it}$	2.742	1.565	0.080	5.780
$FSEC_{it}$	1.101	0.913	0.050	3.990
$FTER_{it}$	0.119	1.628	0.000	0.690
$MPRI_{it}$	3.525	1.301	0.590	6.100
$MSEC_{it}$	1.565	0.890	0.270	4.280
$MTER_{it}$	1.159	0.141	0.000	0.610
$HC_{it} * TFP\ gap_{it}$	0.832	0.735	0.064	4.047
$FHC_{it} * TFP\ gap_{it}$	0.732	0.730	0.015	3.909
$MHC_{it} * TFP\ gap_{it}$	0.939	0.761	0.112	4.193
$FPRI_{it} * TFP\ gap_{it}$	0.493	0.432	0.010	2.105
$FSEC_{it} * TFP\ gap_{it}$	0.215	0.285	0.006	1.663
$FTER_{it} * TFP\ gap_{it}$	0.024	0.035	0.000	0.146
$MPRI_{it} * TFP\ gap_{it}$	0.618	0.441	0.076	2.251
$MSEC_{it} * TFP\ gap_{it}$	0.291	0.309	0.035	1.784
$MTER_{it} * TFP\ gap_{it}$	0.030	0.034	0.000	0.158
FDI_{it}	1.551	1.883	0.001	8.916
$OPENK_{it}$	61.329	42.137	3.989	206.879

Aggregate human capital and female human capital show a significant amount of variation in the dataset. The mean value of human capital is 4.59 years, and range from 0.50 to 10.31 year. Male human capital has greater mean value than the mean of aggregate and female human capital. FDI and trade openness also show wide variation in the dataset with mean value 1.55 and 61.33.

Table 4.2(a)
Correlation Matrix: Aggregate Human Capital Level Specification

Variable	ΔA_{it}	HC_{it}	$TFPgap_{it}$	$HC_{it} * TFPgap_{it}$	FDI_{it}	$OPENK_{it}$
ΔA_{it}	1.00					
HC_{it}	0.32	1.00				
$TFPgap_{it}$	0.10	0.52	1.00			
$HC_{it} * TFPgap_{it}$	0.10	0.52	0.86	1.00		
FDI_{it}	0.07	0.32	0.40	0.37	1.00	
$OPENK_{it}$	0.03	0.52	0.60	0.72	0.52	1.00

The correlation matrixes for the sample countries for different specifications of model in the study are shown in Table 4.2(a), Table 4.2(b), Table 4.2(c) and Table 4.2(d). By referring to Table 4.2(a) that presents the correlation matrix for aggregate human capital level specification. The pairwise correlation between aggregate human capital and the interaction with TFP gap is high (more than 0.80).

Table 4.2(b)
Correlation Matrix: Aggregate Gender-Seperate Human Capital Level Specifications

Variable	ΔA_{it}	FHC_{it}	MHC_{it}	$TFPgap_{it}$	$FHC_{it} * TFPgap_{it}$	$MHC_{it} * TFPgap_{it}$	FDI_{it}	$OPENK_{it}$
ΔA_{it}	1.00							
FHC_{it}	0.29	1.00						
MHC_{it}	0.35	0.96	1.00					
$TFPgap_{it}$	0.10	0.41	0.45	1.00				
$FHC_{it} * TFPgap_{it}$	0.17	0.81	0.81	0.81	1.00			
$MHC_{it} * TFPgap_{it}$	0.20	0.73	0.87	0.89	0.98	1.00		
FDI_{it}	0.07	0.38	0.26	0.40	0.36	0.38	1.00	
$OPENK_{it}$	0.03	0.57	0.55	0.60	0.73	0.70	0.60	1.00

As shown in Table 4.2(b), the correlation matrix for gender-separate human capital specifications, there are high pairwise correlation between the female human capital and the interaction with TFP gap; and male human capital and the interaction with TFP gap.

Table 4.2(c)

Correlation Matrix: Female Human Capital Compisition Level Specifications

Variable	ΔA_{it}	$FPRI_{it}$	$FSEC_{it}$	$FTER_{it}$	$TFPgap_{it}$	$FPRI_{it} * TFPgap_{it}$	$FSEC_{it} * TFPgap_{it}$	$FTER_{it} * TFPgap_{it}$	FDI_{it}	$OPENK_{it}$
ΔA_{it}	1.00									
$FPRI_{it}$	0.31	1.00								
$FSEC_{it}$	0.32	0.82	1.00							
$FTER_{it}$	0.08	0.60	0.71	1.00						
$TFPgap_{it}$	0.10	0.34	0.48	0.34	1.00					
$FPRI_{it} * TFPgap_{it}$	0.20	0.78	0.82	0.58	0.82	1.00				
$FSEC_{it} * TFPgap_{it}$	0.13	0.12	0.86	0.55	0.78	0.92	1.00			
$FTER_{it} * TFPgap_{it}$	0.05	0.61	0.77	0.94	0.84	0.76	0.77	1.00		
FDI_{it}	0.07	0.30	0.25	0.10	0.40	0.40	0.32	0.18	1.00	
$OPENK_{it}$	0.03	0.55	0.55	0.34	0.52	0.74	0.68	0.52	0.52	1.00

Table 4.2(d)

Correlation Matrix: Male Human Capital Compisition Level Specifications

Variable	ΔA_{it}	$MPRI_{it}$	$MSEC_{it}$	$MTER_{it}$	$TFPgap_{it}$	$MPRI_{it} * TFPgap_{it}$	$MSEC_{it} * TFPgap_{it}$	$MTER_{it} * TFPgap_{it}$	FDI_{it}	$OPENK_{it}$
ΔA_{it}	1.00									
$MPRI_{it}$	0.38	1.00								
$MSEC_{it}$	0.27	0.69	1.00							
$MTER_{it}$	0.11	0.44	0.64	1.00						
$TFPgap_{it}$	0.10	0.34	0.48	0.34	1.00					
$MPRI_{it} * TFPgap_{it}$	0.22	0.81	0.71	0.46	0.89	1.00				
$MSEC_{it} * TFPgap_{it}$	0.15	0.54	0.83	0.50	0.84	0.90	1.00			
$MTER_{it} * TFPgap_{it}$	0.08	0.49	0.72	0.89	0.87	0.75	0.79	1.00		
FDI_{it}	0.07	0.26	0.22	0.07	0.40	0.40	0.33	0.21	1.00	
$OPENK_{it}$	0.03	0.53	0.48	0.29	0.60	0.72	0.65	0.53	0.52	1.00

By referring to Table 4.2(c), there is an indication of high colinearity between different levels of female human capital for and the interaction terms of different levels of female human capital with TFP gap.

Table 4.2(d) presents the matrix correlation for male human capital composition level specifications. It shows high collinearity between different levels of male human capital and the interaction with TFP gap.

In summary, there are high pairwise correlations between human capital variables and the interaction terms. The human capital based absorptive capacity is the interaction term between human capital level and TFP gap will cause high collinearity between different levels of human capital and their interaction with TFP gap. The multicolinearity problems do not bias the estimates but increase the value variance of estimation and thus may cause unreliability in the parameter estimation. This study applies the process of orthogonalizing or residual centering technique to reduce multicolinearity by the interaction term (by Burrill, 1997; Little *et al.*, 2006, Geldhof *et al.*, 2013) and examine separately for each level of human capital (as by Benhabib & Spiegel, 2005, Manca, 2011). Variance Inflation Factor (VIF) is examined and presented in the estimation for every empirical model for justification.

4.4 Human Capital Based Absorptive Capacity and Technology Transfer

This section presents the data analysis and estimation results of the impact of human capital on TFP growth directly (through innovation) and indirectly (through technology transfer which is referred to as human capital based absorptive capacity) using the logistic model of technology diffusion by Benhabib and Spiegel (2005).

4.4.1 Average Human Capital Level

Table 4.3 presents the estimation results of Equation (3.4) using pooled OLS, FEM and REM on a balanced panel of 12 developing Asian countries over the period 1970–2009.

The pooled OLS estimation results are shown in Table 4.3, Column 2. The direct effect of aggregate human capital (proxied by average year of total schooling) on TFP is positive and significant at one percent significance level. A one year increase in the average years of total schooling is associated with 0.015 percent increase in TFP growth. The estimated coefficient of technology gap is statistically negative insignificant and the interaction term of human capital and distance to frontier (measured as absorptive capacity) shows an expected negative sign but is insignificant.

Pooled OLS estimator assumes that the error term is identically and independently distributed across countries that are uncorrelated with explanatory variables. However, pooled OLS estimation might result biased and inconsistent estimator if there is unobservable individual effect such as political environment and stability, and schooling environment etc which might affect the TFP growth rate whereby not considered by the pooled OLS estimator. If unobserved individual-specific effects are correlated to the explanatory variables, the estimations by pooled OLS are biased and inconsistent (Hsiao, 1986). In order to solve the problems, this study employs fixed effects and random effects estimators. Columns 3 and 4 of Table 4.3 present the results of estimation using random effects and fixed effects estimator, respectively.

Table 4.3
TFP Growth Estimation of Aggregate Human Capital Based Absorptive Capacity, 1970–2009

Dependent Variable: TFP Growth (ΔA_{it}) **Human Capital : Average years of schooling**					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.006** (3.416)	0.0278 (0.935)	0.156** (3.361)	0.156** (3.101)	-
HC_{it}	0.015* (3.416)	0.017** (3.001)	0.021** (2.397)	0.021** (2.715)	1.36
$TFP\ Gap_{it}$	0.042 (0.295)	-0.300* (-1.682)	-1.299** (-4.397)	-1.299** (-4.486)	1.60
$HC_{it} * TFP\ Gap_{it}$	-0.087 (-1.621)	-0.120** (-2.195)	-0.122* (-1.899)	-0.122** (-2.069)	1.14
FDI_{it}	0.001 (0.215)	0.001 (0.092)	0.004 (0.786)	0.004 (0.988)	1.50
$OPENK_{it}$	-0.001 (-1.312)	-0.001 (-0.274)	0.001 (0.221)	0.001 (0.237)	2.37
Breush-Pagan LM test Restricted F-test		4.67**	 4.39**		
Hausman test			20.03**		
Heteroskedasticity ($\chi^2 - stat$)				316.01**	
Serial Correlation			0.98		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

In comparing pooled OLS with FEM, restricted F-test shows that the FEM is more appropriate than pooled OLS model. Thus, there are country-specific effects in the data. The appropriateness of the FEM versus REM is tested using Hausman test. The Hausman test does reject the null hypothesis that the individual effects are uncorrelated with the explanatory variables in the model. Thus, FEM is more appropriate than random effects model. The null hypothesis of homoskedasticity is rejected implying there is a heteroskedasticity problem in the error term. To correct the heteroskedasticity problem, adjustment is made using robust standard error.

Referring to the estimation results of fixed effects with panel corrected standard error model presents in Column 5 of Table 4.3. The estimated coefficient of average year of schooling is positive and statistically significant at five percent level. A one year increase in the average years of total schooling is associated with 0.021 percent increase in TFP growth. This implies that the notion of human capital is an important factor in facilitating innovation as predicted by the hypothesis and consistent with Benhabib and Spiegel (2005) findings.

Consistent with the hypothesis, the technology gap enters with a significant negative sign at five percent statistical significance level, indicating that other things being constant, countries farther away from technology frontier experience higher rates of productivity growth. The control variables are insignificant.

The coefficient of interaction term of average year of schooling and TFP gap (distance to frontier) has an expected negative sign and statistically significant at five percent significance level with coefficient –0.122 which is in line with the prediction of negative sign in the interaction term by Benhabib and Spiegel (2005). As mentioned in Chapter 3, the interaction term captures the technological catch-up effect whereby the speed of technology transfer depends on the technology gap and human capital stock. The negative coefficient on the human capital interaction term indicates that human capital effectively facilitates international technological transfer and thus leads to high absorptive capacity of technologies as acknowledged by Nelson and Phelps (1966) hypothesis.

By considering the interaction term, the total effect of human capital on TFP growth is captured by the coefficient of human capital and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average human capital is about 0.041 percent [(0.021) (coefficient of human capital) – (–0.122) (coefficient of interaction term) × 0.165 (average TFP gap)]. This shows that the TFP growth effect from the technology gap is higher for higher human capital level.

The coefficient of the total effect of technology gap is –0.748 [(–1.230)(coefficient of technology gap) – (–0.120)(coefficient of interaction term) × (4.594)(average year of total schooling)] suggests that at an average 4.594 years of total schooling, 0.1 unit declines in the technology gap is associated with 0.007 percent increases in TFP growth as countries farther away from the technological frontier be likely to grow faster. As found by Islam (2009) that human capital based absorptive capacity is significant and robust in the samples of OECD and developing countries. The impact of human capital accumulation is found to be significantly positive only for developing countries, thereby supporting and justifying the influential role of human capital in accelerating productivity growth in developing countries (Krueger & Kindahl, 2001). This also consistent with Abreu *et al.* (2004) findings that in line with Nelson and Phelps (1966) hypothesis that technology laggard countries that are farther away from technology frontier tend to have higher TFP growth rates.

The estimated significant positive direct and total effects of human capital on TFP growth present evidence on the importance of human capital on TFP growth through increasing the absorptive capacity. According to Nelson and Phelps (1966) higher human capital investment enhance productivity growth through adoption of foreign technology. The results are consistent with the findings and arguments by recent empirical literature regarding the significant impact of human capital on TFP growth through influence on the ability to absorb and adopt foreign technology and further speeding up rate of technological transfer and also productivity catch-up (e.g. Benhabib & Spiegel, 1994, 2005; Engelbrecht, 2002; Griffith et al., 2004; Kneller & Stevens, 2006; Madsen *et al*., 2010).

4.4.2 Gender Aggregate Human Capital Level

Human capital enhances technological progress through innovation and technology transfer process. To reap the benefits of new technology from abroad, countries must equipped with adequate absorptive capacity to exploit technology transfer efficiently. The absorptive capacity of gender-separate human capital may have different impact on growth in the technology transfer process. This section examines the gender (female and male) impact on TFP growth. Table 4.4 presents the estimation results of the impact of gender aggregate human capital (proxied by gender years of schooling) on TFP growth in Equation (3.5) and Equation (3.6) using pooled OLS, fixed effects and random effects estimators.

In comparing the pooled OLS and FEM, the restricted F-test shows that the FEM is more appropriate than the pooled OLS model as presented in Table 4.4. This implies the presence of country-effects in the data. To test the appropriateness of fixed effects versus random effects, Hausman test is applied. The Hausman statistics does reject the null hypothesis that the country-effects are uncorrelated with the explanatory variables, implying that the fixed effects is more preferable than random effects specification. The null hypothesis of homoskedasticity is rejected indicating there is a heteroskedasticity problem in the error term. To control the heteroskedasticity problem, the estimation results of fixed effects with panel corrected standard error is presented in Table 4.4.

The estimated coefficient of female schooling is positive and statistically significant at five percent level. A one year increase in the average years of female total schooling is estimated to increase the TFP growth rate by 0.018 percent per year. The estimated coefficient of autonomous technology transfer (TFP gap) is negatively significant at five percent level which is consistent with the study's hypothesis. The interaction term between the female schooling and distance to frontier has expected significant statistical negative effect (–0.114) on TFP growth.

The total effect of female schooling on TFP growth is expressed by the coefficient of female human capital and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average female human capital is about 0.036 percent [(0.018)(coefficient of female human capital – (–0.114)(coefficient of interaction term) × (0.165)(average TFP gap)]. This supports the significant absorptive capacity of female human capital in the technological transfer process and further enhancing the TFP growth.

The coefficient of the total effect of technology gap is –0.836 [(1.288)(coefficient of technology gap) – (–0.114)(coefficient of interaction term) × (3.962)(average year of female schooling)] suggests that at sample average 3.962 years of female schooling. This shows that developing Asian countries experienced productivity convergence independent of productivity of female human capital. The control variables in the regression have insignificant estimated coefficients.

Table 4.4

TFP Growth Estimation of Female and Male Human Capital Based Absorptive Capacity, 1970-2009

Dependent Variable:	**TFP Growth (ΔA_{it})**									
Human Capital:	**Female average years of schooling (FHC)**					**Male average years of schooling (MHC)**				
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.010	0.044	0.174**	0.173**	-	-0.027	0.007	0.140**	0.140**	
	(0.485)	(1.543)	(3.793)	(3.471)		(-1.092)	(0.227)	(2.911)	(2.766)	
FHC_{it}	0.013**	0.013**	0.018**	0.018**	1.54					
	(3.049)	(2.598)	(2.072)	(2.321)						
MHC_{it}						0.019**	0.020**	0.022**	0.022**	1.51
						(3.950)	(3.547)	(2.709)	(3.170)	
$TFP\ Gap_{it}$	0.062	-0.280	-1.288**	-1.288**	1.62	0.016	-0.317*	-1.301**	-1.301**	1.65
	(0.435)	(-1.566)	(-4.309)	(-4.372)		(0.110)	(-1.783)	(-4.462)	(-4.622)	
$FHC_{it} * TFP\ Gap_{it}$	-0.084*	-0.114**	-0.114*	-0.114**	1.18					
	(-1.659)	(-2.247)	(-1.912)	(-2.101)						
$MHC_{it} * TFP\ Gap_{it}$						-0.077	-0.106*	-0.112	-0.112*	1.51
						(-1.386)	(-1.809)	(-1.612)	(-1.733)	
FDI_{it}	0.001	0.001	0.004	0.004	1.50	0.002	0.001	0.001	0.001	1.47
	(0.129)	(0.017)	(0.697)	(0.894)		(0.397)	(0.299)	(0.967)	(1.213)	
$OPENK_{it}$	-0.001	-0.001	0.001	0.001	2.57	-0.001	-0.001	0.001	0.001	2.42
	(-1.187)	(-0.071)	(0.428)	(0.457)		(-1.547)	(-0.630)	(-1.300)	(0.001)	
Breush-Pagan LM test		3.31**					2.78**			
Restricted F-test			4.40**					4.28**		
Hausman test			20.10**					19.58**		
Heteroskedasticity ($\chi^2 - stat$)				212.50**					202.34**	
Serial Correlation			0.87					0.72		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

The significant estimated results of the individual and total effects of female schooling on TFP growth support the importance of female education in enhancing the productivity growth (World Bank, 1994) which is in line with Engelbrecht (2002) findings that female schooling (average years of schooling for the female population is significant in the absorption of international technological knowledge. Developing Asian countries have significantly reduced the educational gender disparity (especially in primary education) over the past four decades as mentioned in Section 1.2 whereby in Malaysia and Sri Lanka, the female educational attainment level (in terms of average years of schooling) are higher than male educational attainment in year 2010. Furthermore, the high female labour participation rate in developing Asia also enhance female opportunities and abilities in handling and adapt foreign technological knowledge especially with the fast and widespread use of ICT in the recent decade. For example, Malaysia did well in closing gender gap in education and improves gender parity in the employment of ICT sector (Etzkowitz *et al.*, (2010). De Jong and Tsiachristas (2008) asserted that an increase in female labour participation rate with the ability to adapt foreign technologies may enhance productivity growth and an increase in female educated workers in the workforce will enhance the productivity of a country (Balatchandirane, 2007).

On the other hand, male schooling also has significant impact on TFP growth, as shown in Column 9 of Table 4.4. The estimated coefficient implies that one year increase in the average years of male total schooling would increase the TFP growth rate by 0.022 percent. The estimated coefficient of autonomous technology transfer (TFP gap) is negatively significant at five percent level which is consistent with the study's hypothesis. This shows that developing Asian countries experienced productivity convergence independent of productivity of male human capital. The estimated coefficient interaction term of male schooling is negative (–0.112) and statistically significant at 10 percent level.

The total effect of male schooling on TFP growth is represented by the coefficient of male human capital and interaction term indicated that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average male human capital is about 0.041 percent [(0.022)(coefficient of male human capital) – (–0.112)(coefficient of interaction term) × (0.165)(average TFP gap)]. This indicates that male human capital is a significant absorptive capacity in strengthen the technological transfer process and further enhancing the TFP growth. However, the control variables in the regression have insignificant estimated coefficients.

The coefficient of the total effect of technology gap is –0.714 [(–1.301)(coefficient of technology gap) – (–0.112)(coefficient of interaction term) × (5.250)(average year of male schooling)] suggests that at sample average 5.250 years of male schooling, 0.1 unit increases in the technology gap is associated with 0.007 percent declines in TFP growth as countries farther away from the technological frontier be likely to grow faster.

The estimated results indicate that both female and male schooling are significant in enhancing TFP growth by facilitating the ability of innovation and increases the absorptive capacity of technology transfer as the individual and total gender human capital growth effects are significantly positive. The magnitude coefficients of female and male schooling shows that male schooling (0.022) has a greater individual impact in enhancing TFP growth through rates of innovation than female schooling (0.018) as females are less likely to be involved in technology development or creation especially in high technology sector (Anna *et al.*, 1999).

The significant positively total effects of female and male schooling on TFP growth indicating that increased investments in female education would lead to high absorptive capacity of fostering technology transfer and stimulate developing Asian countries to move closer to the technology frontier [29] and this supports Balatchandirane (2007) argument that an economy with an increasing educated female population will gain higher rate of technology absorption and diffusion, and the rate of investment returns to schooling are higher for female than for male (Psachapolous & Patrinos, 2004). However, the total effect of male schooling on TFP growth is slightly higher than female schooling implies that the speed of absorptive capacity of male schooling in fostering technology transfer is slightly higher than female schooling.

4.4.3 Female Human Capital Composition

Instead of the level of human capital, the impact of the dual roles of technological progress also depends on the composition of human capital (Vandenbussche *et al.*, 2006, Kim & Terada-Hagiwara, 2010). Different levels of gender education level may have different absorptive capacity in facilitating technology transfer and impact on growth as educated female workers are as productive as male workers. Therefore, this study also examines the impact of

[29] According to Human Development Report (2010), increasing in the proportion of women workforce to 70 percent would improve Gross Domestic Product by 2-4 percent in developing such as India and Malaysia.

differences in the level of education by genders on the TFP growth[30]. Table 4.5(a), Table 4.5(b) and Table 4.5(c) present the results of the heterogeneous impact of human capital composition for female on TFP growth; as measured by average years of primary, secondary and tertiary schooling for female population aged 15 and above, separately, in Equation (3.7), Equation (3.8) and Equation (3.9) using pooled OLS, fixed effects and random effects estimators.

In comparing the pooled OLS and FEM, the overall F–test shows that the FEM is more appropriate than pooled OLS model as shown in Table 4.5(a), Table 4.5(b) and Table 4.5(c). This implies the presence of country-effects in the data. In testing the appropriateness of fixed effects versus random effects, the Hausman test is applied. The Hausman statistics reject the null hypothesis that the country-effects are uncorrelated with the explanatory variables, implying that the fixed effects is more preferable than random effects specification. The null hypothesis of homoskedasticity is rejected implying there is a heteroskedasticity problem in the error term. To control the heteroskedasticity problem, the estimation results of fixed effects with panel corrected standard error are presented in Column 5 of Table 4.5(a), Table 4.5(b) and Table 4.5(c).

[30] Engelbert (2002) examined the impact of human capital subcategories of average years of primary schooling , average years of secondary schooling, average schooling in the female and average years of primary schooling in the female population on TFP growth.

Table 4.5(a)

TFP Growth Estimation of Female Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})					
Human Capital	**: Female average years of primary schooling** $(FPRI)$				
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	-0.002 (-0.100)	0.021 (0.769)	0.157** (3.042)	0.157** (2.775)	
$FPRI_{it}$	0.022** (3.396)	0.022** (2.764)	0.021* (1.634)	0.021* (1.719)	1.48
$TFP\ Gap_{it}$	0.110 (0.775)	-0.145 (-0.858)	-1.215** (-3.999)	-1.215** (-4.116)	1.62
$FPRI_{it} * TFP\ Gap_{it}$	-0.121 (-1.198)	-0.182* (-1.720)	-0.226 (-1.623)	-0.226** (-1.925)	1.22
FDI_{it}	0.001 (0.074)	0.001 (0.029)	0.005 (0.966)	0.005 (1.175)	1.51
$OPENK_{it}$	-0.001 (-1.399)	-0.001 (-0.368)	0.001 (0.864)	0.001 (0.908)	2.68
Breush-Pagan LM test		1.45**			
Restricted F-test			3.85**		
Hausman test			20.98**		
Heteroskedasticity $(\chi^2 - stat)$				159.54**	
Serial Correlation			1.08		

Note: Figures in the parentheses are t-statistics. *and ** are the respective 10% and 5% significant levels.

Based on Table 4.5(a) Column 5, the estimated results shows that the individual effect of female primary schooling is statistically positive significant at 10 percent level. The estimated coefficient implies that one year increase in the average years of female primary schooling would increase the TFP growth rate by 0.021 percent. The estimated coefficient of autonomous technology transfer (TFP gap) is negative and statistically significant at the five percent level indicating that developing Asian countries experienced technology convergence, ceteris paribus. The interaction term between female primary schooling and distance to frontier (TFP gap) has an expected significant negative effect on TFP growth with coefficient value –0.226.

The total effect of female primary schooling on TFP growth is represented by the coefficient of female primary human capital and interaction term indicated that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average female primary human capital is about 0.058 percent [(0.021)(coefficient of female primary human capital) – (–0.226)(coefficient of interaction term) × (0.165)(average TFP gap)]. This indicates that female primary human capital is a significant absorptive capacity in strengthen the technological transfer process and further enhancing the TFP growth.

The coefficient of the total effect of technology gap is –0.596 [(–1.215)(coefficient of technology gap) – (–0.226)(coefficient of interaction term) × (2.742)(average year of female primary schooling)] suggests that at sample average 2.742 years of female primary schooling, 0.1 unit increase in the technology gap is associated with 0.006 percent declines in TFP growth. However, the control variables in the regression have insignificant estimated coefficients.

Table 4.5(b)

TFP Growth Estimation of Female Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})					
Human Capital : Female average years of secondary schooling $(FSEC)$					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.028 (1.340)	0.080** (2.678)	0.218** (4.861)	0.218** (4.375)	
$FSEC_{it}$	0.026** (2.273)	0.029** (2.241)	0.042** (2.484)	0.042** (3.200)	1.55
$TFP\ Gap_{it}$	0.032 (0.213)	-0.443** (-2.262)	-1.413** (-4.701)	-1.413** (-4.713)	1.68
$FSEC_{it} * TFP\ Gap_{it}$	-0.212** (-2.008)	-0.267** (-2.649)	-0.256** (-2.344)	-0.256** (-2.503)	1.11
FDI_{it}	0.001 (0.187)	0.001 (0.0684)	0.004 (0.6947)	0.004 (0.8910)	1.47
$OPENK_{it}$	-0.001 (-0.784)	0.001 (0.382)	0.001 (0.502)	0.001 (0.531)	2.31
Breush-Pagan LM test		6.90**			
Restricted F-test			5.33**		
Hausman test			19.66**		
Heteroskedasticity $(\chi^2 - stat)$				280.96**	
Serial Correlation			1.02		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

The estimation results in Table 4.5(b) Column 5 show that the estimated coefficient of female secondary schooling is positive and statistically significant at 5 percent level; an increase of one year in the years of average year of female secondary schooling would increase the TFP growth rate by 0.042 percent. The estimated coefficient of autonomous technology transfer (–1.413) is negative and statistically significant at the five percent level indicating that developing Asian countries experienced technology convergence, ceteris paribus. The interaction term between female secondary schooling and distance to frontier has an expected significant negative effect on TFP growth with coefficient value –0.256 implies that secondary female schooling is important in facilitating technology transfer.

The total TFP growth effect from female secondary schooling is expressed by the coefficient of female secondary schooling and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average female secondary schooling is about 0.084 percent [(0.042)(coefficient of female secondary schooling – (–0.256)(coefficient of interaction term) × (0.165)(average TFP gap)]. This supports the significant absorptive capacity of female secondary schooling in the technological transfer process and further enhancing the TFP growth as found by Engelbrecht (2002). The control variables in the regression have insignificant estimated coefficients.

The coefficient of the total effect of technology gap on TFP growth is –0.131 [(1.413)(coefficient of technology gap) – (–0.256)(coefficient of interaction term) × (1.101)(average year of female secondary schooling)] suggests that at an average 1.101 years of female secondary schooling, 0.1 unit increase in the technology gap is associated with 0.001 percent declines in TFP growth as countries farther away from the technological frontier be likely to enjoy faster productivity growth rate.

Table 4.5(c)

TFP Growth Estimation of Female Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) **Human Capital : Female average years of tertiary schooling** $(FTER)$					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.029 (1.365)	0.080** (2.346)	0.196** (3.976)	0.196** (3.588)	
$FTER_{it}$	0.027 (0.459)	0.057 (0.717)	0.123 (1.676)	0.123* (1.719)	1.20
$TFP\ Gap_{it}$	0.081 (0.532)	-0.406** (-1.917)	-1.221** (-3.836)	-1.221** (-3.741)	1.68
$FTER_{it} * TFP\ Gap_{it}$	-2.449** (-1.986)	-2.702** (-2.448)	-1.906* (-1.618)	-1.906* (-1.620)	1.20
FDI_{it}	-0.001** (0.187)	0.001 (0.132)	0.005 (0.873)	0.005 (0.115)	1.53
$OPENK_{it}$	0.001 (0.187)	0.001 (1.346)	0.001 (1.256)	0.001 (1.378)	2.24
Breush-Pagan LM test		10.61**			
Restricted F-test			4.99**		
Hausman test			13.19**		
Heteroskedasticity ($\chi^2 - stat$)				220.95**	
Serial Correlation			0.49		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Referring to Table 4.5(c), female tertiary schooling has positively significant effect on TFP growth at 10 percent level. The estimated coefficient implies that an increase of one year in the years of average year of female tertiary schooling would increase the TFP growth rate by 0.123 percent. The estimated coefficient of autonomous technology transfer (–1.221) is negative and statistically significant at the five percent level indicating that developing Asian countries experienced technology convergence independent of human capital. The interaction term between female tertiary schooling and distance to frontier has expected significant negative effect on TFP growth with coefficient value –1.906.

By considering the interaction term, the total effect of female tertiary schooling on TFP growth is captured by the coefficient of female tertiary schooling and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of 1 year increase in the average human capital is about 0.437 percent [(0.123) (coefficient of female tertiary schooling) – (–1.906) (coefficient of interaction term) × 0.165 (average TFP gap)]. This shows that the TFP growth effect from the technology gap is higher for higher human capital level.

The coefficient of the total effect of technology gap is –1.760 [(–1.906)(coefficient of technology gap) – (–0.221)(coefficient of interaction term) × (0.119)(average year of female tertiary schooling)] suggests that at an average 0.119 years of female tertiary schooling, 0.1 unit increase in the technology gap is associated with 0.008 percent declines in TFP growth as countries farther away from the technological frontier be likely to grow faster.

The regression results show that all three different levels of female schooling are significant in enhancing TFP growth by increasing the absorptive capacity of technology transfer as support by positive and significant individual and total coefficients at secondary and tertiary schooling. This might be due to the rapid educational attainments progress of female population at all schooling levels since 1980s especially in the primary and secondary schooling levels (in Table 1.6) has increased the literacy level of female population in which improve their ability in absorbing new technological knowledge and become effective workers. The absorptive capacity of female secondary and tertiary schooling is higher than female primary education whereby the total effect coefficients of the female primary, secondary and tertiary schoolings are 0.0579, 0.4368 and 0.4370, respectively. Nonetheless, the significant individual and total impact of female tertiary schooling on productivity growth implying that high skilled or high educated female are efficient in inducing the technology transfer process. This is consistent with Hassan and Cooray (2013) findings on the significant impact of female secondary and tertiary schoolings on economic growth for Asian countries. The individual and total effects of TFP growth show that the TFP growth effect from the technology gap is higher for higher human capital level.

4.4.4 Male Human Capital Composition

The heterogeneous impact of human capital composition for male on TFP growth as in Equation (3.10), Equation (3.11) and Equation (3.12) which measured by average years of primary, secondary and tertiary schooling for male population aged 15 and above is presented in Table 4.6(a), Table 4.6(b) and Table 4.6(c) using pooled OLS, fixed effects and random effects estimators.

The restricted F-test shows that the fixed effects model is more appropriate than pooled OLS model implying the presence of country-effects in the data. In testing the appropriateness of fixed effects versus random effects, the Hausman test is applied. The Hausman statistics does reject the null hypothesis that the country-effects are uncorrelated with the explanatory variables, implying that the fixed effect is more preferable than random effect specifications for male secondary and tertiary schooling. Test for heteroskedasticity reject the null hypothesis of homoskedasticity indicating the presence of heteroskedasticity problems. Column 5 of Tables 4.6(a), 4.6(b) and 4.6(c) present the results of fixed effects with corrected standard error for male primary, secondary and tertiary schooling.

Table 4.6(a)
TFP Growth Estimation of Male Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})
Human Capital : Male average years of primary schooling ($MPRI$)

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	-0.048* (-1.792)	-0.030 (-0.941)	0.119* (1.869)	0.119* (1.734)	
$MPRI_{it}$	0.032** (4.345)	0.034** (3.825)	0.029* (1.770)	0.029* (1.919)	1.45
$TFP\ Gap_{it}$	0.099 (0.709)	-0.104 (-0.638)	-1.197** (-3.856)	-1.197** (-3.944)	1.63
$MPRI_{it} * TFP\ Gap_{it}$	-0.062 (-0.505)	-0.110 (-0.838)	-0.234 (-1.257)	-0.234* (-1.604)	1.20
FDI_{it}	0.002 (0.457)	0.002 (0.420)	0.007 (1.2174)	0.007 (1.483)	1,47
$OPENK_{it}$	-0.001** (-1.965)	-0.001 (-1.201)	0.001 (0.462)	0.001 (0.514)	2.61
Breush-Pagan LM test		0.59			
Restricted F-test			3.36**		
Hausman test			19.25**		
Heteroskedasticity ($\chi^2 - stat$)				156.22**	
Serial Correlation			0.55		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

By referring to Table 4.6(a), the estimated coefficient of male primary schooling is significantly positive at 10 percent significance level; one year increase in male primary schooling is estimated to increase the TFP growth rate by 0.029 percent. The interaction term of male primary schooling also has a significant negative value at five percent significant level.

The total effect of male primary schooling on TFP growth is represented by the coefficient of male primary schooling and interaction term indicated that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of 1 year increase in the average male primary schooling is about 0.068 percent [(0.029)(coefficient of male primary schooling) – (–0.234)(coefficient of interaction term) × (0.165)(average TFP gap)]. This indicates that male human primary schooling is a significant absorptive capacity in strengthen the technological transfer process and further enhancing the TFP growth.

The TFP gap shows the expected significant negative coefficient at five percent statistical significance level supporting the evidence that autonomous technology transfer is a significant determinant of TFP growth. The coefficient of the total effect of technology gap is –0.372 [(–1.197)(coefficient of technology gap) – (–0.234)(coefficient of interaction term) × (3.525)(average year of male primary schooling)] suggests that at an average 5.250 years of male primary schooling, 0.1 unit increase in the technology gap is associated with 0.004 percent declines in TFP growth. However, the control variables in the regression have insignificant estimated coefficients.

Based on Table 4.6(b), the estimated coefficient of male secondary schooling enter the regression significantly positive, one year increase in male secondary schooling is estimated to increase the TFP growth rate by 0.042 percent. The estimated coefficient of autonomous technology transfer (TFP gap) is negatively significant at five percent level which is consistent with the study's hypothesis that developing Asian countries experienced productivity convergence. The interaction terms of male secondary schooling is negative and statistically significant at five percent confidence level.

Table 4.6(b)
TFP Growth Estimation of Male Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})
Human Capital : Male average years o secondary schooling $(\boldsymbol{FSEC})$

Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.013 (0.614)	0.077** (2.466)	0.208** (4.914)	0.208** (4.546)	
$MSEC_{it}$	0.030** (2.615)	0.033** (2.694)	0.042** (2.857)	0.042** (3.518)	1.42
$TFP\ Gap_{it}$	-0.003 (-0.022)	-0.538** (-0.690)	-1.468** (-5.018)	-1.468** (-5.157)	1.74
$MSEC_{it} * TFP\ Gap_{it}$	-0.204* (-1.831)	-0.242** (-2.285)	-0.228** (-2.010)	-0.228** (-2.047)	1.08
FDI_{it}	0.002 (0.330)	0.002 (0.392)	0.005 (1.047)	0.005 (1.310)	1.44
$OPENK_{it}$	-0.001 (-0.718)	0.001 (0.298)	0.001 (0.384)	0.001 (0.391)	2.11
Breush-Pagan LM test		8.23**			
Restricted F-test			5.74**		
Hausman test			19.72**		
Heteroskedasticity $(\chi^2 - stat)$				322.66**	
Serial Correlation			1.13		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

By considering the interaction term, the total effect of male secondary schooling on TFP growth is captured by the coefficient of male secondary schooling and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average male secondary schooling is about 0.080 percent [(0.042) (coefficient of male secondary schooling) – (–0228) (coefficient of interaction term) × 0.165 (average TFP gap)].

The coefficient of the total effect of technology gap is –1.110 [(–0.468)(coefficient of technology gap) – (–0.228)(coefficient of interaction term) × (1.565)(average years of male secondary schooling)] suggests that at an average 1.565 years of male secondary schooling, 0.1 unit increase in the technology gap is associated with 0.011 percent declines in TFP growth indicating that countries farther away from the technological frontier may have higher TFP growth rate.

Table 4.6(c)
TFP Growth Estimation of Male Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) **Human Capital : Male average years of tertiary schooling** $(FTER)$					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.027 (1.227)	0.077** (2.359)	0.199** (4.261)	0.199** (3.853)	
$MTER_{it}$	0.053 (0.792)	0.105 (1.277)	0.200* (1.747)	0.200** (2.126)	1.16
$TFP\ Gap_{it}$	0.070 (0.452)	-0.421** (-2.049)	-1.269** (-4.127)	-1.269** (-4.057)	1.71
$MTER_{it} * TFP\ Gap_{it}$	-1.978* (-1.630)	-2.450** (-2.354)	-1.784* (-1.625)	-1.784* (-1.636)	1.19
FDI_{it}	0.001 (0.133)	0.001 (0.176)	0.004 (0.737)	0.004 (0.933)	1.49
$OPENK_{it}$	0.001 (0.049)	0.001 (1.134)	0.001 (0.842)	0.001 (0.890)	2.19
Breush-Pagan LM test		12.01**			
Restricted F-test			5.50**		
Hausman test			16.11**		
Heteroskedasticity $(\chi^2 - stat)$				285.23**	
Serial Correlation			1.63		

Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

The estimated results in Table 4.6(c) shows that the coefficient of male tertiary schooling is positive and statistically significant at five percent level indicating that one year increase in male tertiary schooling is associated to an increase in the TFP growth rate by 0.199 percent. The relative TFP enter regression with a significantly negative sign, indicating that countries farther away from technological frontier experience higher TFP growth rate. The interaction terms of male tertiary schooling is negative and statistically significant at 10 percent confidence level.

The total effect of male tertiary schooling on TFP growth is expressed by the coefficient of male tertiary schooling and interaction term implies that at the average TFP gap level in the sample (0.165 unit), the TFP growth effect of one year increase in the average male tertiary schooling is about 0.494 percent [(0.200)(coefficient of male tertiary schooling – (–1.784)(coefficient of interaction term) × (0.165)(average TFP gap)]. This supports the important role of male tertiary schooling in enhancing TFP growth through its absorptive capacity on the speed of technology catch-up.

The coefficient of the total effect of technology gap is 0.798 [(– 1.691)(coefficient of technology gap) – (–1.784)(coefficient of interaction term) × (1.159)(average year of male tertiary schooling)] at average 0.012 years of male tertiary schooling. The control variables in the regression have insignificant estimated coefficients.

Same as female schooling, the coefficient value of total effect of male tertiary is higher than male primary and secondary schooling shows that male tertiary schooling has the strongest absorptive capacity in facilitating technology transfer and enhancing TFP growth. The individual and total effects of TFP gap support the evidence that autonomous technology transfer is a significant determinant of TFP growth. This shows that the TFP growth effect from the technology gap is higher for higher human capital level.

The regression results show that female and male tertiary schooling are enhancing TFP growth through its impact on the speed of technology transfer and innovation as presented in Table 4.5(a), Table 4.5(b), Table 4.5(c), Table 4.6(a), Table 4.6(b) and Table 4.6(c). This is contrast with previous studies that only primary and secondary schooling has significant impact on economic growth for Asia countries (e.g. McMahon, 1998 and Bairam & Kulkolkarn, 2001). By extending years of observations in the study, the point estimates results show that the absorptive capacity of tertiary schooling is higher than primary and secondary school in enhancing TFP growth for both genders cases. The results seem to support Manca (2011) findings that high level of education (tertiary schooling) has significant impact in speeding up productivity convergence for developing countries by absorbing and imitating foreign technologies from abroad as he argued that skilled labour is important in enhancing TFP growth for lagging countries' that farther behind the technological frontier. The significant impact of tertiary education on technology transfer could be explained by the increasing labour demand on human capital with higher education level (tertiary education) in the transformation process of developing Asian countries' industrialization policy towards high technology and knowledge intensive manufacturing which may lead to the higher absorptive capacity of tertiary schooling on the speed of technology transfer and innovation (Hassan & Cooray, 2013). World Bank (2012) mentioned that as economies get closer to technological frontier, they need education from all level, particularly tertiary education.

This shows that tertiary education is important in increasing the scientific technical and analytical skills that may effectively handle and induce advanced and high technological knowledge and moving towards innovation because slow tertiary education progress may deteriorate skill shortages (Phan & Coxhead, 2013). It also supports World Bank (2012) argument that tertiary education is important in the technological catch-up process and moving towards innovation for Asian countries that take up a great share of exports require high capacity in adapting technology to customize, design and process products more efficiently and avoid to fall in the middle income trap (ADB, 2010).

This study supports Hassan and Cooray (2013) empirical study on the effects of female and male education on economic growth for Asian countries. They found that female and male primary, secondary and tertiary education have significant impact on growth. They claimed that the significant impact of female and male tertiary education on technology transfer could be explained by the increasing labour demand on human capital with higher education level (tertiary education) as developing Asian countries are moving towards high technology and knowledge intensive manufacturing which may lead to the higher absorptive capacity of tertiary schooling on the speed of technology transfer and innovation. In addition, Hassan and Cooray (2013) presented an argument on the opportunity cost aspect to explain the higher impact of tertiary education on growth that lower income opportunity cost of tertiary education and higher demand on higher education encouraged greater investment in tertiary education and thus speed up the technology transfer process.

Empirical analyses by Ha *et al.* (2009) on a panel data of Asian developed countries on their theoretical model also showed that the closer the distance to the technology frontier, the higher the impact of basic research (highly skilled labour) on economic growth.

Specifically, for higher education level (secondary and tertiary schooling), the point estimates coefficient of interaction term of female secondary and tertiary schooling is higher than the interaction term of male secondary and tertiary schooling. This implies that female tends to have greater absorptive capacity in the technology transfer process at high education level while male absorptive capacity is higher at lower education level[31]. This result is consistent with that of Ang *et al.* (2011) who found that the impact of female tertiary education is greater than male tertiary education for middle income countries on technology diffusion. On the other hand the total impact of male higher education is slightly higher than female education as male innovation has higher impact on TFP growth.

4.5 Endogeneity Issues

The potential endogeneity of schooling data in the growth regression model is argued by Bils and Klenow (2000)[32]. This study tests endogeneity using Durbin-Wu-Hausman test. As suggested by Vandenbussche *et al.* (2006), human capital and the interaction term between human capital and distance to frontier variables are treated as endogenous variables. This study use lagged human capital and interaction term

[31] Engelbrecht (2002) showed that female secondary schooling has significant impact on TFP growth.
[32] Bils and Klenow (2000) shows that the relationship of schooling levels on economic growth could be reverse causality.

with lagged one period [33] as instrument for human capital as adapted by Manca (2011) and Garn (2007). The results are displayed in Table 4.7. The null hypothesis of variable exogenous in the Durbin-Wu-Hausman test cannot be rejected which implies that human capital can be considered as exogenous thus linear regression is applicable.

Table 4.7
Durbin-Wu-Hausman Test for the Endogeneity of Human Capital

Endogenous Instruments	**Durbin-Wu-Hausman**
$\mathrm{FHC}(-1), \mathrm{FHC} * \mathrm{TFPgap} * (-1)$	0.5665 (p=0.7533)
$\mathrm{MHC}(-1), \mathrm{MHC} * \mathrm{TFPgap} * (-1)$	0.0817 (p=0.9600)
$\mathrm{HC}(-1), \mathrm{HC} * \mathrm{TFPgap} * (-1)$	0.7655 (p=0.6820)
$\mathrm{FPRI}(-1), \mathrm{FPRI} * \mathrm{TFPgap} * (-1)$	3.7155 (p=0.1560)
$\mathrm{FSEC}(-1), \mathrm{FSEC} * \mathrm{TFPgap} * (-1)$	0.1604 (p=0.9229)
$\mathrm{FTER}(-1), \mathrm{FTER} * \mathrm{TFPgap} * (-1)$	0.7920 (p=0.6730)
$\mathrm{MPRI}(-1), \mathrm{MPRI} * \mathrm{TFPgap} * (-1)$	4.6779 (p=0.0964)
$\mathrm{MSEC}(-1), \mathrm{MSEC} * \mathrm{TFPgap} * (-1)$	0.3501 (p=0.8394)
$\mathrm{MTER}(-1), \mathrm{MTER} * \mathrm{TFPgap} * (-1)$	1.1529 (p=0.5619)

4.6 Robustness Checks

The sensitivity checks are carried out to examine the robustness of the results presented in section 4.4 to an alternative measurement of variables of human capital and include more control variables.

[33] In Vandebusche et al. (2006), the instruments are the explanatory variables lagged two periods. Their model's explanatory variables are lagged one period.

4.6.1 Alternative Data Set of Human Capital Attainment

The robustness checks of the results to an alternative data set of human capital attainment from the International Institute for Applied Systems (IIASA) and the Vienna Institute of Demography (VID) (hereforth IIV). There are four non-overlapping categories of schooling data provided by IIV: no schooling (p_1), primary (p_2), secondary (p_3) and tertiary schooling (p_4), in which the number of years (n) of completion for each category of education is (n_1, n_2, n_3, n_4) = {0, 6, 6, 4}. Average years of primary, secondary and tertiary schooling for female and male population aged 15 and above are constructed follow Ang *et al.* (2011) method for these variables, thus, $FPRI\ or\ MPRI = (p_2 + p_3 + p_4)(n_2) + (p_3 + p_4)(n_3)$; $or\ MSEC = (p_3 + p_4)(n_4) + (p_4)(n_5)$; and $FTER\ or\ MTER = p_4 n_4$. Average years of total schooling for female and male population for aged 25 and above are calculated as $FPRI + FSEC + FTER$ and $MPRI + MSEC + MTER$, respectively. Table 4.8 and Table 4.9 present the estimation results for total schooling, female and male schooling from IIV data sets in Equation (3.15), Equation (3.16) and Equation (3.17).

In Table 4.8 and Table 4.9, the restricted F-test shows that fixed effects model is more appropriate than pooled OLS model as there are country-specific effects in the data. The Hausman test reject the null hypothesis that the country-effects are uncorrelated with the explanatory variables, thus, fixed effects is more preferred than random effects model. To control the heteroskedasticity problems, fixed effects with corrected standard error is show in Table 4.8 and Table 4.9.

The regression results show that average years of total schooling has significant positive effects on TFP growth for developing Asian counties at 10 percent significant level and the impact of autonomous technology is negatively significant at five percent significant level. The interaction terms between the total schooling and distance to frontier also have significant expected negative effects on TFP growth. Furthermore, at average TFP gap in the sample, the total effects of total schooling on TFP growth is positively significant with coefficient value of 0.038. and the total effect of technology gap is –0.442. The results are broadly consistent with the average years of schooling in Table 4.3.

Table 4.8
TFP Growth Estimation of Aggregate Human Capital Based Absorptive Capacity, 1970-2009

Dependent Variable: TFP Growth (ΔA_{it})
Human Capital : Average year of Total Schooling (HC)

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	-0.011 (-0.380)	0.001 (0.019)	0.132** (2.007)	0.132** (1.683)	
HC_{it}	0.011** (2.539)	0.012** (2.379)	0.016* (1.716)	0.016* (1.683)	1.55
$TFP\ Gap_{it}$	0.041 (0.276)	-0.149 (1.400)	-1.312** (-3.634)	-1.312** (-3.485)	1.78
$HC_{it} * TFP\ Gap_{it}$	-0.117* (-1.779)	-0.015** (-2.131)	-0.137 (-1.546)	-0.137* (-1.757)	1.30
FDI_{it}	0.007 (0.9738)	0.004 (0.656)	0.008 (1.240)	0.008 (1.202)	1.79
$OPENK_{it}$	-0.001 (-1.029)	-0.001 (-0.219)	0.001 (0.853)	0.001 (0.830)	3.14
Breush-Pagan LM test		0.69			
Restricted F-test			3.26**		
Hausman test			17.11**		
Heteroskedasticity ($\chi^2 - stat$)				162.96**	
Serial Correlation			0.46		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.9

TFP Growth Estimation of Female and Male Human Capital Based Absorptive Capacity, 1970-2009

Dependent Variable:	**TFP Growth (ΔA_{it})**									
Human Capital :	**Female average years of schooling (FHC)**					**Male average years of schooling (MHC)**				
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.006 (0.237)	0.020 (0.678)	0.134** (2.255)	0.134** (2.255)		-0.061* (-1.652)	-0.050 (-1.133)	0.100 (1.323)	0.100 (1.247)	
FHC_{it}	0.009** (2.283)	0.010** (2.121)	0.016* (1.767)	0.016* (1.767)	1.62					
MHC_{it}						0.017** (3.082)	0.018** (2.894)	0.019* (1.897)	0.019* (1.860)	1.51
$TFP\ Gap_{it}$	0.085 (0.554)	-0.161 (-0.875)	-1.291** (-3.585)	-1.291** (-3.585)	1.78	0.084 (0.552)	-0.118 (-0.636)	-1.259** (-3.439)	-1.259** (-3.343)	1.79
$FHC_{it} * TFP\ Gap$	-0.106* (-1.780)	-0.147** (-2.393)	-0.171** (-2.143)	-0.171** (-2.143)	1.32					
$MHC_{it} * TFP\ Gap$						-0.112 (-1.522)	-0.128* (-1.732)	-0.101 (-1.124)	-0.101 (-1.224)	1.22
FDI_{it}	0.001 (0.091)	-0.001 (-0.455)	-0.002 (-0.217)	-0.001 (-0.217)	1.79	0.001 (0.114)	-0.001 (-0.199)	0.003 (0.405)	0.003 (0.482)	1.70
$OPENK_{it}$	-0.001 (-0.770)	0.001 (0.328)	0.001 (1.407)	0.001 (1.407)	3.25	-0.001 (-1.067)	-0.000 (-0.325)	0.001 (0.664)	0.001 (0.631)	2.87
Breush-Pagan LM test		1.54					0.85			
Restricted F-test			3.88**					3.64**		
Hausman test			19.12**					15.54**		
Heteroskedasticity ($\chi^2 - stat$)				271.07**					265.76**	
Serial Correlation			0.67					0.37		

Note: Figures in the parentheses are t-statistics. *and ** are the respective 10% and 5% significant levels.

For aggregate female and male schooling, the estimation results shown in Table 4.9 also consistently in line with those reported in Table 4.4. The direct and indirect impacts of female and male schooling on TFP growth are statistically significant. The individual coefficients of female total schooling and male total schooling are 0.016 and 0.019, respectively, with 10 percent significance level. In term of the total effect of human capital on TFP growth for both genders, the coefficient values also positively significant, 0.044 and 0.035, respectively. These results provide evidence on the importance of female and male education for technology transfer. The effect of autonomous technology on TFP growth is significantly negative in term of female and male schooling with coefficients –0.355 and – 0.529, respectively. This is in line with the theoretical prediction.

The estimation regression results of the human capital composition for female is shown in Table 4.10(a), Table 4.10(b) and Table 4.10(c). The results are quite similar with those obtained in Table 4.5(a), Table 4.5(b) and Table 4.5(c), respectively.

Table 4.10(a)

TFP Growth Estimation of Female Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})					
Human Capital : Female average years o primary schooling $(FPRI)$					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	-0.002 (-0.071)	0.012 (0.384)	0.094 (1.411)	0.094 (1.282)	
$FPRI_{it}$	0.015** (2.123)	0.015* (1.813)	0.031* (1.831)	0.031* (1.621)	1.63
$TFP\ Gap_{it}$	0.154 (0.999)	-0.071 (-0.401)	-1.231** (-3.317)	-1.231** (-3.234)	1.76
$FPRI_{it} * TFP\ Gap_{it}$	-0.188* (-1.619)	-0.283** (-2.360)	-0.371** (-2.017)	-0.371** (-2.141)	1.23
FDI_{it}	0.001 (0.109)	-0.001 (-0.278)	-0.001 (-0.105)	-0.001 (-0.126)	1.78
$OPENK_{it}$	-0.001 (-1.025)	0.012 (0.384)	0.001 (1.578)	0.001 (1.443)	3.16
Breush-Pagan LM test		1.84*			
Restricted F-test			4.19**		
Hausman test			22.63**		
Heteroskedasticity $(\chi^2 - stat)$				212.60**	
Serial Correlation			0.63		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.10(b)

TFP Growth Estimation of Female Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})					
Human Capital : Female average years of secondary schooling ($FSEC$)					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.018 (0.842)	0.033 (1.231)	0.172** (3.17)	0.172** (2.396)	
$FSEC_{it}$	0.025** (2.507)	0.028** (2.472)	0.0367* (1.667)	0.037* (1.772)	1.49
$TFP\ Gap_{it}$	-0.003 (-0.021)	-0.201 (-1.095)	-1.317** (-3.638)	-1.317** (-3.066)	1.90
$FSEC_{it} * TFP\ Gap_{it}$	-0.249** (-2.035)	-0.292** (-2.345)	-0.282* (-1.785)	-0.282** (-2.206)	1.33
FDI_{it}	0.001 (0.172)	-0.002 (-0.342)	-0.001 (-0.052)	-0.001 (-0.065)	1.75
$OPENK_{it}$	-0.001 (-0.367)	0.001 (0.371)	0.001 (0.966)	0.001 (1.088)	3.03
Breush-Pagan LM test		1.06			
Restricted F-test			3.45**		
Hausman test			17.30**		
Heteroskedasticity ($\chi^2 - stat$)				334.17**	
Serial Correlation			0.62		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.10(c)

TFP Growth Estimation of Female Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})
Human Capital : Female average years of tertiary schooling ($FTER$)

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	0.035 (1.587)	0.065** (2.185)	0.215** (4.101)	0.215** (3.922)	
$FTER_{it}$	0.028 (0.718)	0.039 (1.050)	0.033* (1.731)	0.033* (1.841)	1.25
$TFP\ Gap_{it}$	0.159 (0.992)	-0.108 (-0.534)	-1.221** (-3.171)	-1.221** (-3.162)	1.77
$FTER_{it} * TFP\ Gap_{it}$	-0.562 (-1.325)	-0.820* (-1.794)	-0.941 (-1.482)	-0.941* (-1.599)	1.10
FDI_{it}	0.006 (0.917)	0.003 (0.406)	0.005 (0.620)	0.005 (0.726)	1.64
$OPENK_{it}$	-0.001 (-1.078)	-0.001 (-0.156)	0.001 (1.035)	0.001 (1.227)	2.28
Breush-Pagan LM test		2.99**			
Restricted F-test		4.06**			
Hausman test			1714**		
Heteroskedasticity ($\chi^2 - stat$)				306.79**	
Serial Correlation			0.90		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Referring to Table 4.10(a), Table 4.10(b) and Table 4.10(c), the growth effect of the female primary, secondary and tertiary schooling are positive 0.031 (coefficient of female primary schooling), 0.037, (coefficient of female secondary schooling) and 0.033 (coefficient of female tertiary schooling)].The estimated coefficients of interaction term and technology gap have expected statistically significant negative impact on TFP growth. Total effects of female primary, secondary and tertiary schooling on TFP growth are positively significant, in which, one year increase in female primary, secondary and tertiary schooling have 0.036, 0.083 and 0.188 percent TFP growth at sample average TFP gap. The total effects of TFP gap on TFP growth is –1.121, –0.834 and –1.053, respectively, negatively associated with TFP growth in which in line with the hypothesis.

The estimation regression results of the human capital composition for male presents in Table 4.11(a), Table 4.11(b) and Table 4.11(c) are also quite similar with those obtained in Table 4.6(a), Table 4.6(b) and Table 4.6(c), respectively.

Table 4.11(a)
TFP Growth Estimation of Male Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) Human Capital : Male average years of primary schooling ($MPRI$)					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	-0.0038 (-0.1583)	0.0010 (0.035)	0.130* (1.857)	0.130* (1.739)	
$MPRI_{it}$	0.021** (3.007)	0.021** (2.899)	0.023 (1.110)	0.023* (1.684)	1.44
$TFP\ Gap_{it}$	-0.053 (-0.330)	-0.141 (-0.855)	-1.230** (-3.307)	-1.230** (-3.220)	2.04
$MPRI_{it} * TFP\ Gap_{it}$	-0.259* (-1.953)	-0.299** (-2.275)	-0.295 (-1.494)	-0.295* (-1.735)	1.70
FDI_{it}	0.001 (0.020)	-0.002 (-0.326)	-0.002 (-0.1788)	-0.002 (-0.197)	1.79
$OPENK_{it}$	-0.000 (-0.010)	0.000 (0.476)	0.001 (1.344)	0.001 (1.299)	3.79
Breush-Pagan LM test		0.72			
Restricted F-test			2.8263**		
Hausman test			17.84**		
Heteroskedasticity ($\chi^2 - stat$)				123.86**	
Serial Correlation			0.59		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.11 (b)

TFP Growth Estimation of Male Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) **Human Capital : Male average years of secondary schooling $(MSEC)$**					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.028 (1.322)	0.056** (2.014)	0.209** (4.745)	0.209** (3.718)	
$MSEC_{it}$	0.030* (1.860)	0.031* (1.842)	0.038 (1.548)	0.038* (1.667)	1.97
$TFP\ Gap_{it}$	-0.051 (-0.302)	-0.298 (-1.501)	-1.393** (-3.897)	-1.393** (-3.638)	2.20
$MSEC_{it} * TFP\ Gap_{it}$	-0.291** (-2.566)	-0.348** (-3.091)	-0.342** (-2.645)	-0.342** (-2.733)	1.22
FDI_{it}	0.001 (0.177)	-0.003 (-0.532)	-0.001 (-0.184)	-0.001 (-0.234)	1.73
$OPENK_{it}$	-0.000 (-0.207)	0.000 (0.574)	0.001 (0.850)	0.001 (0.779)	2.75
Breush-Pagan LM test		3.77**			
Restricted F-test			4.20**		
Hausman test			18.27**		
Heteroskedasticity $(\chi^2 - stat)$				469.43**	
Serial Correlation			0.61		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.11 (c)

TFP Growth Estimation of Male Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) **Human Capital : Male average years of tertiary schooling $(MTER)$**					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.033 (1.515)	0.052* (1.798)	0.194** (3.372)	0.194** (3.019)	
$MTER_{it}$	-0.018 (-0.353)	-0.025 (-0.375)	-0.273* (-1.901)	-0.273** (-2.001)	1.15
$TFP\ Gap_{it}$	0.068 (0.427)	-0.193 (-0.996)	-1.374** (-3.565)	-1.374** (-3.477)	1.84
$MTER_{it} * TFP\ Gap_{it}$	-3.727** (-2.791)	-4.117** (-3.386)	-4.099** (-2.870)	-4.099** (-2.929)	1.27
FDI_{it}	0.002 (0.299)	-0.002 (-0.300)	0.002 (0.317)	0.002 (0.396)	1.71
$OPENK_{it}$	0.000 (0.483)	0.001* (1.720)	0.002** (3.141)	0.002** (3.187)	2.83
Breush-Pagan LM test		4.76**			
Restricted F-test			4.38**		
Hausman test			18.38**		
Heteroskedasticity $(\chi^2 - stat)$				185.22**	
Serial Correlation			0.74		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant level.

By referring to Table 4.11(a), Table 4.11(b) and Table 4.11(c), only the estimated coefficient of male primary, secondary and tertiary schooling are significantly positive. The TFP gap shows the expected significant negative coefficient at five percent statistical significance level. The interaction term of male primary, secondary and tertiary schooling also have significant negative values.

The total effect of male primary, secondary and tertiary schooling on TFP growth are positively about 0.018 percent, 0.094 percent and 0.389 percent, respectively. This indicates that male primary, secondary and tertiary schooling are significant absorptive capacity in strengthen the technological transfer process and further enhancing the TFP growth. The coefficients of the total effect of technology gap is –0.123, –0.569 and –0.370 at average male primary, secondary and tertiary schooling, respectively, as countries farther away from the technological frontier be likely to grow faster.

Overall the results are plausibly consistent with the estimation results with the specification of individual and total effects of aggregate human capital, gender human capital and also gender human capital composition on TFP growth as presented in Section 4.4.1, Section 4.4.2, Section 4.4.3 and Section 4.4.4.

4.6.2 Include More Control Variables

The robustness checks of the estimation to include more control variables in the regression, that is, democracy level and political instability which are measured by the POLITY IV index (POLITY) and Major Episodes of Political Violence (MEPV) index (SI), respectively. Table 4.12 and Table 4.13 present the estimation results of the TFP growth effect of aggregate human capital and gender–separate human capital, respectively.

Referring to Table 4.12 and Table 4.13 , the estimation results are largely consistent with the empirical findings in Section 4.4.1 and Section 4.4.2, thus, reinforcing the robustness of the empirical finding that gender-separate human capital are important factors in enhancing TFP growth for developing Asian countries.

Table 4.12

TFP Growth Estimation of Aggregate Human Capital Based Absorptive Capacity, 1970-2009

Dependent Variable: TFP Growth (ΔA_{it})					
Human Capital : Average Years of Total Schooling (HC)					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.005 (0.200)	0.049 (1.416)	0.161** (3.442)	0.161** (3.033)	
HC_{it}	0.017** (3.586)	0.019** (2.959)	0.024** (2.705)	0.024** (3.033)	1.57
$TFP\ Gap_{it}$	0.041 (0.284)	-0.428** (-2.157)	-0.140** (-4.566)	-0.140** (-4.957)	1.20
$HC_{it} * TFP\ Gap_{it}$	-0.095* (-1.729)	-0.129** (-2.226)	-1.440** (-2.173)	-1.440** (-2.357)	1.67
FDI_{it}	-0.001 (-0.091)	-0.001 (-0.115)	0.003 (0.598)	0.003 (0.695)	1.68
$OPENK_{it}$	-0.001 (-1.597)	-0.000 (-0.238)	0.000 (0.454)	0.000 (0.469)	2.53
$POLITY_{it}$	0.000 (0.200)	-0.000 (0.214)	-0.003 (-1.447)	-0.003 (-1.512)	1.14
SI_{it}	-0.005 (-1.298)	-0.004 (-1.074)	-0.003 (-0.908)	-0.003 (-0.855)	1.36
Breush-Pagan LM test		3.76**			
Restricted F-test			4.40***		
Hausman test			18.50***		
Heteroskedasticity ($\chi^2 - stat$)				193.50***	
Serial Correlation			0.98		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.13

TFP Growth Estimation of Female and Male Human Capital Based Absorptive Capacity, 1970-2009

Dependent Variable: TFP Growth (ΔA_{it})

Human Capital:	**Female average years of schooling (FHC)**					**Male average years of schooling (MHC)**				
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.022 (0.938)	0.066** (1.982)	0.180** (3.886)	0.180** (3.747)		-0.0018 (-0.707)	0.027 (0.743)	0.143** (2.989)	0.143** (2.989)	
FHC_{it}	0.014** (3.179)	0.015** (2.526)	0.021** (2.382)	0.021** (2.650)	1.77					
MHC_{it}						0.022** (4.142)	0.023** (3.510)	0.025** (2.997)	0.025** (2.997)	1.76
$TFP\ Gap_{it}$	0.059 (0.407)	-0.412** (-2.057)	-1.388** (-4.451)	-1.388** (-4.853)	1,68	0.016 (0.115)	-0.438** (-0.230)	-1.401** (-4.614)	-1.401** (-4.614)	1.70
$FHC_{it} * TFP\ Gap_{it}$	-0.089* (-1.721)	-0.121** (-2.243)	-0.134** (-2.163)	-0.134** (-2.368)	1.22					
$MHC_{it} * TFP\ Gap_{it}$						-0.090* (-1.650)	-0.115* (-1.859)	-0.134* (-1.871)	-0.134* (-1.871)	1.21
FDI_{it}	-0.001 (-0.137)	-0.001 (-0.163)	0.003 (0.513)	0.003 (0.599)	1,68	0.000 (0.012)	0.000 (0.038)	0.004 (0.787)	0.004 (0.788)	1.64
$OPENK_{it}$	-0.001 (-1.436)	-0.000 (-0.011)	0.000 (0.637)	0.000 (0.657)	2.74	-0.001** (-1.842)	-0.000 (-0.608)	0.000 (0.249)	0.000 (0.249)	2.55

$POLITY_{it}$	0.001 (0.353)	-0.000 (-0.063)	-0.003 (-1.346)	-0.003 (-1.426)	1.15	0.000 (0.023)	-0.001 (-0.322)	-0.003 (-1.447)	-0.003 (-1.447)	1.18
SI_{it}	-0.004 (-1.125)	-0.003 (-0.920)	-0.003 (-0.814)	-0.003 (-0.774)	1.35	-0.005* (-1.456)	-0.004 (-1.231)	-0.003 (-0.999)	-0.003 (-0.999)	1.36
Breush-Pagan LM test		2.27*					2.93**			
Restricted F-test			4.40**					4.27**		
Hausman test			18.18**					18.16**		
Heteroskedasticity ($\chi^2 - stat$)				127.70**					251.90**	
Serial Correlation			0.82					0.62		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.14(a), Table 4.14(b) and Table 4.14(c) present the estimation results for female primary, secondary and tertiary schooling, respectively.

Table 4.14 (a)
TFP Growth Estimation of Female Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})
Human Capital : Female average years of primary schooling ($FPRI$)

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	0.010 (0.398)	0.041 (1.253)	0.157** (3.006)	0.157** (2.807)	
$FPRI_{it}$	0.024** (3.504)	0.023** (2.473)	0.025 (1.556)	0.025* (1.657)	1.65
$TFP\ Gap_{it}$	0.102 (0.700)	-0.253 (-1.341)	-1.288** (-4.089)	-1.288** (-4.379)	1.18
$FPRI_{it} * TFP\ Gap_{it}$	-0.129 (-1.257)	-0.196* (-1.732)	-0.257* (-1.790)	-0.257** (-2.047)	1.24
FDI_{it}	-0.001 (-0.104)	-0.000 (-0.053)	0.005 (0.841)	0.005 (0.967)	1.68
$OPENK_{it}$	-0.001* (-1.652)	-0.000 (-0.236)	0.001 (1.026)	0.001 (1.038)	2.84
$POLITY_{it}$	0.001 (0.680)	0.001 (0.379)	-0.002 (-1.082)	-0.002 (-1.184)	1.11
SI_{it}	-0.004 (-1.071)	-0.003 (-0.769)	-0.002 (-0.549)	-0.002 (-0.527)	1.32
Breush-Pagan LM test		1.84*			
Restricted F-test			3.72**		
Hausman test			18.66**		
Heteroskedasticity ($\chi^2 - stat$)				212.60**	
Serial Correlation			0.71		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels

Table 4.14(b)

TFP Growth Estimation of Female Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})

Human Capital : Female average years of secondary schooling $(FSEC)$

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	0.038 (1.568)	0.111** (3.081)	0.232** (5.053)	0.232** (4.912)	
$FSEC_{it}$	0.029** (2.348)	0.034** (2.384)	0.046** (2.726)	0.046** (3.441)	1.75
$TFP\ Gap_{it}$	0.029 (0.193)	-0.606** (-2.785)	-1.516** (-4.855)	-1.516** (-5.277)	1.72
$FSEC_{it} * TFP\ Gap_{it}$	-0.224** (-2.009)	-0.283** (-2.651)	-0.295** (-2.612)	-0.295** (-2.832)	1.21
FDI_{it}	-0.001 (-0.008)	-0.001 (-0.094)	0.003 (0.495)	0.003 (0.594)	1.65
$OPENK_{it}$	-0.000 (-0.949)	0.000 (0.400)	0.001 (0.781)	0.001 (0.834)	2.44
$POLITY_{it}$	0.000 (0.104)	-0.001 (-0.338)	-0.003 (-1.368)	-0.003 (-1.419)	1.21
SI_{it}	-0.003 (-0.826)	-0.003 (-0.970)	-0.003 (0.992)	-0.003 (0.945)	1.33
Breush-Pagan LM test		1.06			
Restricted F-test			5.47**		
Hausman test			17.62**		
Heteroskedasticity $(\chi^2 - stat)$				334.17**	
Serial Cirrelation			0.88		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.14(c)
TFP Growth Estimation of Female Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})
Human Capital : Female average years of tertiary schooling $(FTER)$

Variable	OLS	Random Effects	Fixed Effects	Fixed Effects with Corrected Standard Errors	VIF
$Constant$	0.032 (1.289)	0.098** (2.527)	0.205** (4.064)	0.205** (3.913)	
$FTER_{it}$	0.024 (0.366)	0.079 (0.882)	0.149 (1.270)	0.149* (1.603)	1.42
$TFP\ Gap_{it}$	0.072 (0.460)	-0.498** (-2.182)	-1.280** (-3.902)	-1.280** (-4.026)	1.71
$FTER_{it} * TFP\ Gap_{it}$	-2.304* (-1.776)	-2.700** (-2.317)	-2.222* (-1.813)	-2.222* (-1.827)	1.30
FDI_{it}	0.000 (0.003)	0.000 (0.540)	0.004 (0.667)	0.004 (0.810)	1.70
$OPENK_{it}$	0.000 (0.105)	0.001 (1.252)	0.001 (1.407)	0.001 (1.559)	2.36
$POLITY_{it}$	0.001 (0.442)	-0.000 (-0.153)	-0.002 (-0.995)	-0.002 (-1.059)	1.24
SI_{it}	-0.000 (-0.045)	-0.002 (-0.637)	-0.003 (-0.801)	-0.003 (-0.785)	1.34
Breush-Pagan LM test		2.99**			
Restricted F-test			5.05**		
Hausman test			12.87**		
Heteroskedasticity $(\chi^2 - stat)$				306.79**	
Serial Correlation			1.30		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

The individual and total effects of female primary, secondary and tertiary schooling on TFP growth are positively significant, suggesting that the advantages of technological catch-up can be cultivated by Asian developing countries through increasing investment in education. The results are consistently with those reported in Section 4.4.3, thus supporting the robustness of the results.

The TFP growth effects of different education level of male population are shown in Table 4.15(a), Table 4.15(b) and Table 4.15(c).

Table 4.15 (a)

TFP Growth Estimation of Male Primary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it}) **Human Capital : Male average years of primary schooling ($MPRI$)**					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	-0.039 (-1.402)	-0.015 (-0.390)	0.116* (1.815)	0.116* (1.699)	
$MPRI_{it}$	0.035** (4.468)	0.036** (3.537)	0.033** (1.955)	0.033** (2.098)	1.63
$TFP\ Gap_{it}$	0.097 (0.682)	-0.189 (-1.039)	-1.265** (-3.895)	-1.265** (-4.652)	1.69
$MPRI_{it} * TFP\ Gap_{it}$	-0.078 (-0.642)	-0.128 (-0.905)	-0.274 (-1.419)	-0.274* (-1.620)	1.23
FDI_{it}	0.001 (0.157)	0.001 (0.210)	0.006 (1.108)	0.006 (1.284)	1.64
$OPENK_{it}$	-0.001** (-2.241)	-0.000 (-1.113)	0.001 (0.640)	0.001 (0.677)	2.74
$POLITY_{it}$	0.001 (0.440)	0.000 (0.254)	-0.002 (-1.065)	-0.002 (-1.143)	1.13
SI_{it}	-0.005 (-1.341)	-0.003 (-1.064)	-0.002 (-0.634)	-0.002 (-0.604)	1.34
Breush-Pagan LM test		1.84*			
Restricted F-test			3.21**		
Hausman test			17.42**		
Heteroskedasticity ($\chi^2 - stat$)				212.60**	
Serial Correlation			0.53		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.15 (b)

TFP Growth Estimation of Male Secondary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})

Human Capital : Male average years of secondary schooling $(\boldsymbol{MSEC})$

Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.021 (0.855)	0.107** (2.949)	0.221** (5.145)	0.221** (5.108)	
$MSEC_{it}$	0.031** (2.629)	0.035** (2.833)	0.046** (3.096)	0.046** (3.721)	1.56
$TFP\ Gap_{it}$	-0.006 (-0.038)	-0.707** (-3.205)	-1.578** (-5.183)	-1.578** (-5.723)	1.77
$MSEC_{it} * TFP\ Gap_{it}$	-0.215* (-1.826)	-0.255** (-2.305)	-0.265** (-2.274)	-0.265** (-2.354)	1.20
FDI_{it}	0.001 (0.151)	0.001 (0.243)	0.005 (0.875)	0.005 (1.028)	1.61
$OPENK_{it}$	-0.000 (-0.833)	0.000 (0.326)	0.001 (0.707)	0.001 (0.732)	2.19
$POLITY_{it}$	0.000 (0.107)	-0.001 (-0.437)	-0.003* (-1.655)	-0.003 (-1.480)	1.22
SI_{it}	-0.003 (-0.718)	-0.003 (-1.032)	-0.004 (-1.079)	-0.004 (-1.015)	1.28
Breush-Pagan LM test		1.06			
Restricted F-test			5.96**		
Hausman test			17.91**		
Heteroskedasticity $(\chi^2 - stat)$				334.17**	
Serial Correlation			0.92		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

Table 4.15(c)

TFP Growth Estimation of Male Tertiary Education Based Absorptive Capacity, 1970-2009

Dependent Variable : TFP Growth (ΔA_{it})					
Human Capital : Male average years of tertiary schooling ($MTER$)					
Variable	**OLS**	**Random Effects**	**Fixed Effects**	**Fixed Effects with Corrected Standard Errors**	**VIF**
$Constant$	0.029 (1.180)	0.091** (2.553)	0.209** (4.426)	0.209** (4.289)	
$MTER_{it}$	0.048 (0.641)	0.136 (1.503)	0.241** (2.043)	0.241** (2.519)	1.78
$TFP\ Gap_{it}$	0.064 (0.408)	-0.488** (-2.263)	-1.353** (-4.274)	-1.353** (-4.461)	2.21
$MTER_{it} * TFP\ Gap_{it}$	-1.837 (-1.419)	-2.561** (-2.326)	-2.243** (-1.951)	-2.243** (-1.973)	1.22
FDI_{it}	0.001 (0.188)	0.000 (0.025)	0.003 (0.448)	0.003 (0.531)	1.70
$OPENK_{it}$	-0.000 (-0.020)	0.000 (1.066)	0.001 (1.096)	0.001 (1.167)	2.35
$POLITY_{it}$	0.001 (0.347)	-0.001 (-0.389)	-0.003 (-1.334)	-0.003 (-1.376)	1.26
SI_{it}	-0.000 (-0.030)	-0.003 (-0.821)	-0.004 (-1.062)	-0.004 (-1.014)	1.31
Breush-Pagan LM test		2.99**			
Restricted F-test			5.72**		
Hausman test			17.37**		
Heteroskedasticity ($\chi^2 - stat$)				306.79**	
Serial Correlation			0.54		

Note: Figures in the parentheses are t-statistics. * and ** are the respective 10% and 5% significant levels.

The estimation results of individual and total effects of male primary, secondary and tertiary on TFP growth are significantly positive, indicating the important role of male human capital in enhancing TFP growth through technological transfer process. The results are consistently with those reported in

Section 4.4.4, thus reinforcing the evidence that the results in Section 4.4.4 are reasonably robust.

4.7 Conclusion

This section discusses the estimation results of the regression specifications in the study. The empirical investigation is to examine the role of TFP contribution in the Asian developing countries and explore the role of gender-separate human capital and its' composition in the technology transfer process and to estimate the effects on TFP growth. This study found robust results on the importance role of separate-gender human capital and their different level education in speeding up the technology catch-up process. The regression results also support the technology catch-up hypothesis that countries farther behind the technological frontier will experience higher growth rate in TFP. These results are robust to robustness checks by considering the use of alternative measures of human capital and the inclusion of more control variables.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

A stylized fact in the contemporary economic growth theory is that, in sustaining the growth of a country, TFP is increasingly become more important than capital accumulation as capital accumulation of capital is subject to diminishing marginal return. Sources driving the impressive growth performance of developing Asian countries have been discussed and the controversial issue is whether output growth is driven by factor accumulation or by TFP growth which is divided into two main theories – assimilation and accumulation theories. TFP or technology progress is important in the paradigm shift process of developing Asia countries from low-income countries to middle income countries and therefore converges to high income countries. Innovation and technology transfer are the two main sources in technology progress. As developing countries, technology progress in developing Asia depends highly on technology transfer process rather than innovation in enhancing their TFP growth and catching-up to the technology frontier. Human ability is important in determining the extent of technology transfer in developing Asia countries and further enhancing the TFP growth and leadings them to the convergence path. The different absorptive levels of education (commonly referred as proxy for human capital) by genders have different impact in enhancing TFP growth by facilitating technology transfer from abroad in the developing Asian countries.

As noted in Chapter 1, this study attempts to investigate: 1] the contribution of TFP growth in the developing Asian countries; 2] the effect of autonomous technology transfer on TFP growth 3] the direct impact (innovation) of human capital on TFP growth and 4] the indirectly effects (technology transfer) of human capital based absorptive capacity on TFP growth in the developing Asian countries.

Based on the aforementioned objectives of this study, the summary of empirical findings and recommendations are presented in this Chapter.

5.2 Summary of Findings

Based on the empirical results in Chapter 4, this section discusses the summary of the findings of this study.

The first objective of this study is investigating the contribution of TFP growth to economic growth for the developing Asian countries using growth accounting exercises throughout the period of 1970–2009. The results from the growth accounting calculation showed that TFP growth generally has been the important driver for economic growth of developing Asia. Specifically, TFP growth showed significant contribution to the output growth for the post-2000 period. Therefore, the results of this study seem to support the assimilation views (Sarel, 1996; Klenow & Rodriguez-Clare,1997 and Hsieh, 2002) that economic growth of the Asian countries were dominated by TFP growth. The increasing pattern of TFP growth indicates that developing Asian countries attained TFP gains were due to the diffusion of technology from abroad which may lead them catching-up to the technological frontier.

International transfer of technology has been recognised as a major source of productivity growth for developing countries and the extent of technology transfer is determined by the ability of recipient country to extract global technology efficiently. This study estimated the role of human capital in enhancing TFP growth through innovation and technology transfer based on logistic technology diffusion model in a panel sample of 12 developing Asian countries over the period 1970–2009. Three different estimators are applied, such as POLS, fixed effects and random effects estimation.

The empirical results in this study found that aggregate human capital enhances TFP growth through dual mechanisms of technological progress that comprises innovation and technology transfer, this implying that aggregate human capital based absorptive capacity is robust in the technology catch-up process for developing Asian countries. From gender perspective, both aggregate female and male education are significant in absorbing and adapting foreign technologies. However, the technological absorptive capacity of aggregate male education is slightly higher than aggregate female education in enhancing TFP growth. Generally, the findings of this study on the impact of aggregate human capital (for total, female and male population) on TFP growth in the innovation and technology transfer process are in line with the theoretical prediction by Benhabib and Spiegel (2005).

The heterogenous impacts of gender disaggregate human capital levels on TFP growth, the estimation results show that female primary, secondary and tertiary educations are important in enhancing TFP growth and induce developing Asian countries to move closer to technological frontier. For male, primary, secondary and tertiary educations also are significant in inducing the technology transfer process. The findings show that higher education level (tertiary schooling) based absorptive capacity has greater impact on productivity convergence than lower education level (primary and secondary schoolings) for both genders. This indicates that tertiary education is a significant absorptive capacity in facilitating technology transfer and enhancing TFP growth in the developing Asian countries. Thus, the findings seem to support the argument present by this study that emphasized the role of tertiary education is effective in facilitating the technology transfer process and enhancing TFP growth of developing countries.

Similarly, the direct impact of tertiary education level on TFP growth is larger than lower education levels – primary and secondary – for both genders. This implies that workers with tertiary education are more innovative than those with lower education. Autonomous technology transfer are found to be significantly negative, this support the backwardness advantages argument that countries' farther away from frontier gain more on TFP growth.

5.3 Policy Implications and Recommendations

The findings of this study propose some insights on policy implications and recommendations for developing Asian countries.

5.3.1 Promote Further the Growth and Contribution of TFP

Based on the estimation results of Solow neoclassical growth accounting, the total factor productivity appears to be the main factor that driving the economic growth of developing Asian countries over the period 1970–2009. In their convergence pathway to reach high income countries, to further increase the contribution of TFP growth, developing Asian countries should increase their technological progress by emphasising the development of technology innovation and transfer as these two are the main sources of technological progress. Development policies should promote structural change, higher savings; improve education system to produce more skilled labours and enhance human ability in facilitating technology transfer, improve the accessible and application of ICT, and encourage technological development and innovation.

5.3.2 Enhance Flow of Technology Transfer of Foreign Technologies Developed Elsewhere

In order to enhance the technology transfer process, developing Asian countries should continue to strengthen the accessible and technological absorptive capacity. In term of foreign technology accessibility, developing countries should further increase the degree of trade liberalization policies and attract more FDI. Developing Asian countries should increase also the access of ICT by providing broader internet services with lower price and encourage involvement in high-tech industries rather than low-tech and labour intensive industries.

5.3.3 Further Improve the Progress of the Educational Attainment

The significance of human capital in explaining TFP growth in developing Asian countries implies that human resource is a key factor in innovation activities and technology transfer process. Thus, developing human capital skills is an important task for developing Asian countries to catch-up to or narrows the technological frontier. Education policy of these countries should expand education at all levels by providing free and compulsory basic education up to upper secondary schooling, raise public spending on education and increase opportunities for further studies at tertiary education level. In addition, developing Asian countries also need to encourage children in rural area to attend school by providing adequate facilities and incentives. Enhance the human ability to ensure better absorption of technology process by providing better education environment and increase quality of education whereby emphasizing the science, technology, engineering and mathematic subjects.

5.3.4 Encourage and Augment Tertiary Education

The findings of this study show that tertiary education of both genders has significant effects on TFP growth through both innovations and technology transfer process. Therefore, developing Asian countries must focus to broaden and step up their efforts in developing and enhancing the skills of the labour force by expanding educational access of tertiary education in their development process to high income countries and catch-up to the technology frontier. Developing Asian countries can increase the participation rate of tertiary education by expanding the establishment of private higher educational institutions to create more opportunities for students to continue study in tertiary education with less financial burden. Provide financial support for students to further their studies in tertiary level, for example, the establishment of The National Higher Education Fund Corporation (PTPTN) in 1997 by the Malaysian government. In addition, the quality of tertiary education also needs to be emphasised.

5.3.5 Reduce Gender Education Inequality

In term of gender perspective, the absorptive capacity of aggregate female human capital is significant in facilitating technology transfer in enhancing TFP growth. Developing Asian countries should expand female education as a whole and tertiary education specifically. Improve education comprehensively from education policy to teacher quality and curricula and materials must be well developed to be gender-responsive (Elborgh-Woytek *et al.*, 2013). In addition, developing Asian countries should put more initiatives to encourage and increase female basic education by improving infrastructure and secure safety in schools for example roads leading to schools and school facilities (Ucan, 2012), reduce the high private education cost by implementing financial support scheme for poor families sending their girls to school such as the conditional cash transfer (CCT) program[34] (Saavedra & Garcia, 2012) for example Bangladesh implements female secondary school stipend program to encourage the attendance of female primary and secondary schooling levels. Developing Asian governments also need to increase the public expenditure on secondary school which will increase female school enrollment rates which as implemented by Brazil government (OECD, 2011).

In addition, it is important for developing Asian countries to reduce the gender educational discrimination at higher education level because female tertiary educational capital stock has a greater impact than male on TFP growth in facilitating technology transfer process [35] . However, female tertiary education level of developing countries is still lagging behind that of male tertiary education level.

[34] CCT program has been implemented by developing countries to encourage poor families send their children especially girls by providing money transfer.
[35] Dollar and Gati (1999) and Busse and Nunnenkamp (2009) stated that higher female education levels (secondary and tertiary education) have greater impact on economic growth for developing countries.

Therefore, developing Asian countries has to increase educational opportunities for females at tertiary level to enhance the technology transfer process by promoting full and equal education for female, providing equitable access to appropriate education programmes, knowledge and career opportunities. In term of funding mechanism, it can be done by increasing female enrolment rates in existing public universities and private universities and providing special financial assistance or scholarship for female students in tertiary education. Incentives and increase opportunities should be provided for married women to further study in tertiary education by introducing open and flexible distance learning such as offering flexible study schedules with more options in time to avoid time conflict. Government of developing Asian countries may encourage female employment by reducing gender wages disparity and discrimination to enhance TFP growth and technology transfer process. In order to further enhance the female tertiary education based absorptive capacity, there is a need to encourage and increase female involvement in science, engineering and information technology (IT) areas in the tertiary education by referring to the cooperation of The Asia-Pacific Economic Cooperation (APEC), Industrial Science and Technology Working Group (ISTWG) and the Telecommunications Working Group (TELWG) which put efforts to identify ways to enhance women's participation in science and technology education.

5.3.6 Enhance Female Labour Force Participation and Industry Employment

Female education has great impact on TFP growth in the innovation and technology transfer process thus policymakers can integrate policies to encourage and increase female employment rate by providing free childcare services, concerning on whether labour market provide great access for female in better employment opportunities. The high female absorptive capacity of technology transfer indicated that female have strong ability to master and apply foreign technology. This findings justified that industrial sector should provide more opportunities for female participation in the production and management process that involves high technology application and IT.

5.4 Recommendation for Future Research

This paper suggests some recommendations that should be considered for future research. Besides quantity of human capital, quality of human capital and demographic dimension of human capital are important to explain the dual dimensions of productivity growth – innovation and technology transfer of across countries. Therefore, investigating the impacts of quality and demographic dimension of human capital on TFP growth in the developing Asian countries could be recommended for further research.

Other than education level measures, other form measures of human capital such as technical skills, amount of science and technology workforce should be consider in the TFP growth model to examine the impact of technology transfer.

Further analysis should also consider other factors of technology transfer absorptive capacity in developing Asia such as R&D expenditure and government pro-active policies in explaining the TFP growth.

5.5 Conclusion

This chapter summarized the findings of this study and propose some insights on policy implications and recommendations. TFP growth is an important driver in the economic growth of developing Asian countries. This study also examines the implications for TFP growth of the role of gender separate human capital in the technology transfer process in the developing Asian countries by highlighting the gender human capital composition. In summary, the regression results show that female human capital is important in speeding up the technological catch-up process. Specifically, higher gender human capital level has greater impact. Corresponding to the results, this study proposes some policy implication to the developing Asian countries to augment the TFP growth and increase the female human capital in the technology transfer process and further enhance TFP growth.

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APPENDIX

Appendix A1

Solution for Benhabib and Spiegel (2005)

Assuming that the leader is growing at a rate of g_L, we can write $A_{max,t} = A_{max,0}e^{g_L{}^t}$. Thus, equation (2.10) in the text can be rewritten as follows:

$$\frac{\dot{A_i}(t)}{\{A_i(t)\}^2} - \frac{(g_i+c_i)}{A_i(t)} = -\frac{(c_i e^{-g_L{}^t})}{A_{max}(0)} \quad (2.10a)$$

Substituting $(t) = \frac{1}{A_i(t)}$, we get $(-\dot{y}(t)) = \frac{\dot{A_i}(t)}{\{A_i(t)\}^2}$. Hence, equation [g] changes to

$$-\dot{y}(t) - \frac{(g_i+c_i)}{y(t)} = -\frac{(c_i e^{-g_L{}^t})}{A_{max}(0)} \quad (2.10b)$$

where $g_i = g(H_i(t))$.

Multiplying both sides by the integrating factor $e^{(g_i+c_i)^t}$ and integrating yields:

$$e^{(g_i+c_i)^t}y(t) = \frac{\left\{c_i e^{(g_i+c_i-g\,max)^t}\right\}}{A_L(0)(g_i+c_i+g_{max})} + K \quad (2.10c)$$

As the general solution where K is integrating constant. Evaluating the solution at a value of $t = 0$ generates K, which is equal to $\frac{1}{A_i(t)} - \frac{c_i}{A_L(0)(g_i+c_i+g_{max})}$ and hence $A_i(t)$ can be written as:

$$A_i(t) = \frac{\left[A_i(0)e^{(g_i+c_i)t}\right]}{\left[1+\left\{\frac{A_i(0)}{A_{max}(0)}\right\}\frac{c_i}{c_i+g_i-g_{max}}\right]\left\{e^{(g_i+c_i-g_{max})t}-1\right\}} \quad (2.10d)$$

Simplifying further it turns out as:

$$A_i(t) = \frac{\left[A_{max}(0)e^{g_{max}{}^t}\right]}{\left[e^{-(g_i+c_i-g_{max})t}\left(\frac{A_i(0)}{A_{max}(0)} - \frac{c_i}{c_i+g_i-g_{max}}\right)+\frac{c_i}{c_i+g_i-g_{max}}\right]} \quad (2.10e)$$

So that in limit,

$$\lim_{1\rightarrow\infty} A(t) \Big/ A(t)^{max} = \begin{pmatrix} \frac{(c_i+g_i-g_{max})}{c_i} & & (c_i + g_i - g_{max}) > 0 \\ \frac{A_i(0)}{A_{max}(0)} & if & (c_i + g_i - g_{max}) = 0 \\ 0 & & (c_i + g_i - g_{max}) < 0 \end{pmatrix}$$

(2.10f)

The technological distance between the best-practice technology level and current technology level is as follows:

$$B_{it} = \frac{A_{it}}{A_0^*} e^{-g_m t}, \text{ for all } i \quad (3.14a)$$

Differentiating equation – with respect to time yields,

$$\frac{\dot{B_{it}}}{B_{it}} = \frac{\dot{A_{it}}}{A_{it}} - gm \quad (3.14b)$$

For the case of confined exponential case,

$$\frac{\dot{B_{it}}}{B_{it}} = c(HC_{it})\left({B_{it}}^{-1} - 1\right) + g(HC_{it}) - g(HC_m) \quad (3.14c)$$

For the case of logistic case,

$$\frac{\dot{B_{it}}}{B_{it}} = c(HC_{it})(1 - B_{it}) + g(HC_{it}) - g(HC_m) \quad (3.14d)$$

The specification of technology diffusion that nests the both cases (Equation 3.14c and 3.14e) can be expressed as,

$$\frac{\dot{B_{it}}}{B_{it}} = \frac{c(HC_{it})}{s}(1 - {B_{it}}^{s}) + g(HC_{it}) - g(HC_m) \quad (3.14e)$$

$$\dot{B} = \left(\frac{c(HC_{it}) + sg(HC_{it}) - sg(HC_m)}{s}\right) B - \frac{c(HC_{it})}{s} B^{s+1} \quad (3.14f)$$

$$\dot{B} = \left(\frac{c(HC_{it}) + sg(HC_{it}) - sg(HC_m)}{s}\right) B \left(1 - \left(\frac{B^S}{(1 + \frac{s(g_i - gm)}{c_i})}\right)\right) \quad (3.14g)$$

with $s \in [-1,1]$. Note that if $s = 1$, this specification is logistic model and if $s = -1$, it is confined exponential model.

Table A1: Variables Sources and Definitions

Variable	Sources and definition
$\Delta \ln A$	Total factor productivity Growth is calculated from the 7.0 version of the Penn World Table (PWT7.1 – Heston, Summers and Aten, 2012) available at http://pwt.wcon.upenn.edu/php_site/pwt_index.php
SCH	Barro and Lee (2010) the average years of schooling for total, female and male population ages 15 years and above
$SCH * TFP\ gap$	Human capital based technology transfer (absorptive capacity) measured by the interaction between SCH and $TFP\ gap$.
$TFP\ gap$	Autonomous technology transfer
OPENK	Openness ratio to gross domestic product at 2005 constant prices ($OPENK$) obtained from Penn World Table 7.1.
FDI	Percentage of foreign direct investment inflows to gross domestic product (FDI) obtained from UCTAD (United Nations Conference on Trade and development) Interactive Database.

Table A2: List of Countries

Bangladesh
China
India
Indonesia
Malaysia
Nepal
Pakistan
Papua New Guinea
Philippines
Sri Lanka
Thailand
Vietnam

Table A3
Average Annual TFP growth without Labour-Quality Adjustment (in %; labour shares = 0.6)

	1970 – 1980	1980 – 1990	1990 – 2000	2000 – 2007
China	2.38 (35.4)	3.35 (40.2)	4.43 (48.7)	6.54 (58.9)
India	0.30 (8.4)	2.09 (38.7)	1.36 (28.6)	2.33 (34.5)
Indonesia	2.34 (29.7)	0.35 (6.2)	0.28 (6.6)	2.61 (57.8)
Malaysia	2.52 (27.8)	0.77 (13.2)	1.99 (26.8)	2.32 (44.7)
Pakistan	1.37 (26.9)	2.05 (34.3)	0.02 (0.6)	2.09 (33.8)
Philippines	0.93 (16.2)	-0.88 (-43.8)	0.78 (20.7)	2.29 (47.2)
Thailand	2.02 (29.7)	2.83 (37.6)	0.49 (12.8)	3.32 (68.9)
Vietnam	-1..08 (-28.7)	2.39 (42.0)	0.80 (12.4)	1.96 (26.6)

Source: Park (2010)