Economic Growth, Welfare and Foreign Workers: Case of Singapore

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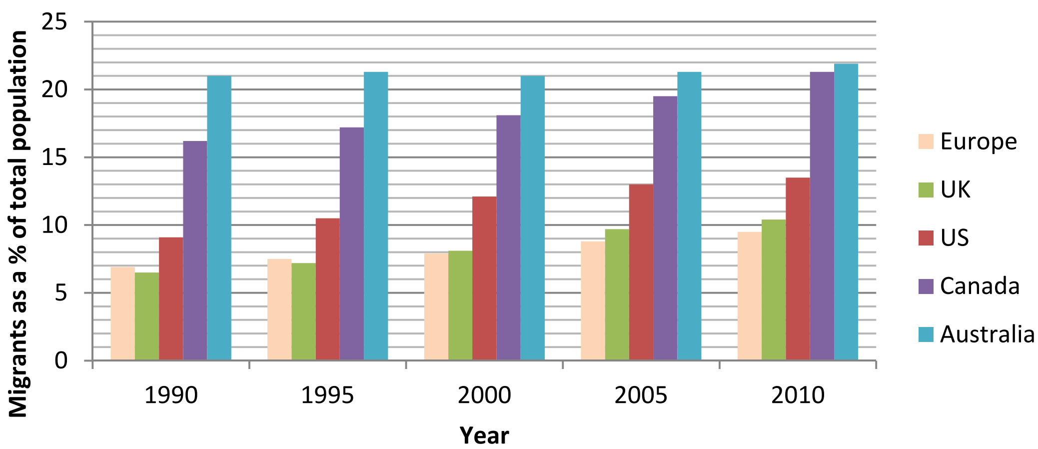
Abstract

According to Borjas (1995), the welfare impact of foreign workers or immigration surplus is defined as the increase in income of the native population in the host country as a result of immigration. The current paper studies the impact of immigrants on the growth of the Singapore economy by developing a dynamic general equilibrium model of Drinkwater, Levine, Lotti and Pearlman (2007). The model accounts for the flow of skilled and unskilled foreign workers on (a) steady-state growth, (b) wage gap between the skilled and unskilled, and (c) innovation capabilities of the domestic economy. Further, the model also accounts for the contribution of immigrants on the welfare of the domestic economy through the immigration surplus that will accrue to domestic economy.

1. Introduction

In a globalized environment, immigrant labour is an important source of human capital to complement and enhance economic growth. In the past 2 decades, international labor mobility is increasingly becoming an important component to drive global trade and integration. Between 1990 and 2010, it has been estimated that the stock of international migrants has increased from 155 million to almost 215 million, and is growing at an average annual growth rate of 3.3 percent.[2] In most cases, migrants are moving to developed countries such as the European Union, United States, United Kingdom, Canada, and Australia, which is reflected by the growing proportion of migrants in these countries as shown in Figure 1.

FIGURE 1: MIGRANTS AS A PERCENTAGE OF TOTAL POPULATION, 1990 - 2010



Source: International Labor Migrant Stock, 2010 (United Nations)

Recent studies highlight that the inflow of skilled immigrants could increase the expected returns on education and the host economy could benefit from inflow of skilled immigrants in terms of complementing the domestic human capital and

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[2] Figures retrieved from the United Nations website, "International Migrant Stock: 2008 Revision", http://esa.un.org/migration/index.asp?panel=1.

increasing the domestic innovation activities (Vidal, 1988; Mountford, 1999; Stark and Wang, 2002; Chander and Thangavelu, 2005). Migrant workers can be an important source of human capital for economic growth. Recent studies point to the positive effect of highly-skilled immigrants on innovative activities in the domestic economy; increasing innovation and generating beneficial spillover effects on the economy (Stephan and Levin, 2001; Peri, 2007; Hunt and Gauthier-Loiselle, 2008; Chellaraj, Maskus, and Mattoo, 2008).

However, recent empirical evidence indicates that the productive impact of immigrants depends on their level of skills and the natives, and also on the host economy's domestic productive capacity to "absorb" foreign labour. For example, the study by Borjas and Hanson (2008), Ottaviano and Peri (2008), and Peri and Sparber (2009) indicate that the effects of immigrants on the domestic economy depend on the skilled characteristics of the native and immigrant workers in the production process. Recent evidence on the U.S. economy suggests that immigrants increase total factor productivity (TFP) through efficient task specialization in the labour market, however, promoting the adoption of unskilled-biased technology due to a large inflow of unskilled workers (Peri, 2009). The study on U.K. and Spain highlights different impact of immigrants on the domestic economy, where immigrants have more productive impact in the U.K. as compared to Spain (Kangasniemi et al., 2008).

Several other studies have also shown that less-skilled immigrants may cause a shift towards labor-intensive techniques, as a result of efforts to complement the less-skilled migrant workers (Acemoglu, 1998; Lewis, 2005; Peri, 2007; Chia, 2007; Thangavelu, 2010). These studies imply that the impact of immigration on technological progress depends largely on the skill level of migrant workers and the characteristics of the host economy. The effect of immigration on wages is less clear cut, as some studies find an improvement in average native wages (Ottaviano and Peri, 2006; Card, 2007; Peri, 2008), while others report an overall decline (Borjas,2003; Aydemir and Borjas, 2006). There is less ambiguity on the issue of wage inequality, which is found to be alleviated if foreign labor is mostly high-skilled, and aggravated if they are generally low-skilled (Aydemir and Borjas, 2006; Peri,2008).

Despite an explosive volume of research on the wage effect of immigrants, the literature has yet to reach a consensus. In a recent study, Peri (2009) predicts a 0.5% increase in income per worker as a result of 1% increase in employment due to immigration inflow, while Borjas (2003) finds that recent immigration puts downward pressure on the native workforce wages, particularly for unskilled workers. Borjas (2009) further argued that the short-run wage effect is most likely to be negative and that the long-run effect may be negative if the size of the consumer base expands less than that of the workforce as a result of immigration. Card (2004) uses empirical evidence to show that in high-immigration cities of U.S., firms adapt to the changes in relative supplies of workers with different skill levels by adjusting their production technology, and there is no significant change in the relative wage rates after immigration. Chang (2002) uses Taiwanese data to calibrate a dynamic inter-temporal general equilibrium model, and concludes that foreign workers exert a negative impact on the local unskilled workers by widening the wage gap. Recent study by Choy (2004) for the Korean economy shows that the positive impact of immigration critically depends on the price flexibility in the economy and there are larger welfare gains if the immigration policy is skilled-biased.

More recent studies highlight the importance of general equilibrium framework to study and quantify the impact of immigrants on the domestic economy. There are several key advantages of competitive general equilibrium models. Partial equilibrium that focuses on single markets mainly neglects the effects of other markets on its equilibrium. In a general equilibrium framework, the choices of economic agents in the economy are explicitly accounted and coordinated across all products and factor markets. Thus a general equilibrium model provides the framework to study (a) impact of random shocks on economy, (c) factors affecting the long-term steady-state growth of the economy, (c) institutional and structural changes on the welfare of the agents, and (d) impact of policy changes on domestic markets and welfare of the agents.

According to Borjas (1995), the immigration surplus is defined as the increase in income of the native population in the host country as a result of immigration due to lower cost of labour, increase in capital investments, and overall productivity improvements from skilled immigrants. He shows a 10% increase in workforce from immigrant workers, the GDP of U.S. economy increases by nearly 0.105%. This is accompanied by a 3% fall in the wage rate with no significant re-distributional effects between capital and labour. He also highlights that the immigration of skilled workers will generate higher immigration surplus due to the complementarity of skilled labour and capital investments. Levine, Lotti and Pearlman (LLP) (2003) revisited Borjas' work by calibrating a three-sector general equilibrium model with endogenous growth to the European Union economies, and redefined immigration surplus in terms of the increase in welfare levels among the natives in the post-immigration era. The above studies conclude that unskilled immigration has negative impact on the size of immigration surplus and in support of immigration policies favoring the skilled immigrants.

We will follow LLP's three-sector general equilibrium model and calibrate the model to the Singapore context, and examine the economic impact of changing the skill-composition of the immigrant workforce on the long-term growth rate, size of the innovative sector, wage rates and the welfare-based immigration surplus. Singapore is an interesting country to study the immigration surplus as it allows both skilled and unskilled immigrant workers into the economy. This inflow of skilled and unskilled will allow us to model the trade-offs of productivity and wage effects of immigrant workers on the welfare of the economy.

Borjas (1995) highlighted that the magnitude of immigration surplus depends on the differences of skill components between the native and the immigrant workers, and it could reach a maximum level when the immigration inflow is sufficiently different from that of the native work force, i.e. when their production complementarities are fully exploited. He also pointed out that underlying the immigration surplus lays a significant redistribution of wealth from the native workers to the employers of the immigrant workers, and the surplus only arises when immigrants lower the wage rate of native workers. This raises the issue of potentially harmful impact on the wage gap in the indigenous labour market.

Drinkwater, Levine, Lotti and Pearlman (DLLP) (2007) revisited Borjas' work by calibrating a three-sector general equilibrium model with endogenous growth to the European Union economies, and redefined immigration surplus in terms of the increase in welfare levels among the natives in the post-immigration era. These studies conclude that unskilled immigration has negative impact on the size of immigration surplus and in support of immigration policies favoring the skilled immigrants. By comparing their results with that of Borjas (1995), they concluded that the positive effect of skilled immigrants is larger in the dynamic case than that of the Borjas' static case. Skilled immigrants tend to increase the long-term growth by stimulating 'more skill-intensive R&D activities' in the innovative sector. There are gains in growth and the immigration surplus increases further when there is complementarity between skilled workers and physical capital.

In the current paper, we adopt the Drinkwater, Levine, Lotti and Pearlman's three-sector general equilibrium model with endogenous growth (2007) and calibrate to the Singapore economy. The paper models three major sectors in the Singapore economy: a labour-intensive service sector which is assumed to produce a homogenous good, and the value-added goes to our physical capital accumulation; a capital-intensive manufacturing sector which produces differentiated goods with growing varieties; and an innovative sector, which is assumed to be the engine of growth of the economy that conducts the necessary research activities for new product development. All sectors employ three factor inputs, namely the skilled workers, unskilled workers and physical capital. Since there is no closed-form solution to our general model, we will adopt a numerical method and narrow down our scope to the steady-state analysis.

The paper is organized as follows. The next section provides the literature review. Section 3 gives an overview of the international labour mobility in Asia. We discuss the foreign manpower policy in Singapore in section 4. We discuss the theoretical model and the simulation results at section 5. We give the policy conclusions at section 6.

2. LITERATURE REVIEW

2.1 Wage Impacts

The importance and impact of international labor mobility on output growth is an important area of study. This has motivated extensive research efforts to ascertain the local labor market impacts of immigration, such as labor demographics, activity and participation rates, wages, employment, technology adoption, and productivity. Most studies have focused on wage effects, but empirical results are inconclusive at best. In a departure from the 'spatial correlation' framework[3] typically used to analyze the labor market impacts of immigration, Borjas (2003) introduced a model which assumes that workers with similar educational qualifications, but differing experience levels, are imperfect substitutes. Using data from the United States covering the period 1980 - 2000, Borjas reported that immigration caused average native wages in the U.S. to decrease by 3.2 percent, with low-skilled (high school dropouts) workers suffering the greatest decline of 8.9 percent. Aydemir and Borjas (2006) applied the methodological framework developed by Borjas (2003) in a comparative study of Canada, Mexico, and the United States, and found a negative impact of immigration on native wages in the U.S. and Canada. The reverse is observed for Mexico, as the economy experiences net emigration. A dissimilar impact of migration on the wage structure in the U.S. and Canada is highlighted, which is attributed to the average skill level of migrants. Aydemir and Borjas (2006) highlighted that Canada attracts mostly high-skilled immigrants, while migrants to the U.S. are disproportionately low-skilled. As a result, immigration has reduced wage inequality in Canada, while increasing it in the United States

[3] Since Grossman (1982), most empirical studies have exploited the clustering of immigrants in particular areas to study the labor market impacts of immigration. After identifying an area as the labor market experiencing immigration, these studies compute a 'spatial correlation' which measures the relationship between native wages and the relative number of immigrants in that area.

Empirical studies have not always found the wage impact of immigration to be negative. In an extension of the framework developed by Borjas (2003), Ottaviano and Peri (2006) used a general equilibrium approach and established a positive effect of immigration on the average wage of native U.S. workers. Approximately 90 per cent of native workers experienced real wage gains, while the remaining 10 percent, comprising of high school dropouts, suffered a less severe real wage loss of 1.1% as compared to earlier estimates. Moreover, any adverse wage effect of immigration is mainly borne by earlier generations of immigrants. A positive effect of immigration on native wages was also found in separate studies by Card (2007) and Peri (2008), despite a large proportion of low-skilled amongst the migrant populations examined. However, Card (2007) pointed out that positive labor market impacts of migration could be negated by perceived negative externalities posed by immigrants. An interesting finding from Peri (2008) was the rapid adjustment of capital to immigrant inflows, which kept capital intensity relatively constant. In addition, workers of all skill groups experienced productivity gains from immigration. The favorable responses of capital and productivity compensated for the adverse relative supply effect and resulted in very small wage effects for low-skilled workers. On the other hand, high-skilled workers experienced significant and positive wage effects accruing from the affirmative capital, productivity, and labor supply effects.

2.2 Technology Adoption

The impact of foreign workers on technological development can be a double-edged sword. On one hand, skilled immigrants may be complementary to the native labor force, introducing skills which are relevant to promoting new innovation and technological progress. A study by Hunt and Gauthier-Loiselle (2008) showed that skilled immigrants – college graduates, postgraduates, scientists and engineers –

increased innovation in the U.S., and had positive spillover effects on native innovation. In fact, native inventors were not crowded out by foreign-born inventors, as these skilled immigrants increased per capita patenting without decreasing native patenting. The positive impact of skilled immigrants on innovation is supported by Peri (2007). Using patents as a proxy for innovation, it is found that foreign-born Ph.D.s contributed significantly to innovation in the U.S., and increasing the share of Ph.D.s in the country by 3% would increase innovation rates and TFP growth by 1% a year. Other studies have also highlighted the significant and positive contributions of skilled immigrants, particularly scientists and engineers, to innovation in the host economy (Stephan and Levin, 2001; Chellaraj, Maskus, and Mattoo, 2008).

On the other hand, unskilled immigrants with low human capital may reduce the incentive of firms to innovate, increasing their tendency to shift towards cheaper and more labor-intensive production. In a cross-sectional study of the impact of skill mix in U.S. labor markets on the adoption of manufacturing automation technologies, Lewis (2005) found that technology adoption in the U.S. manufacturing sector is strongly and negatively influenced by the relative supply of low-skilled labor. As immigration increases the relative supply of low-skilled labor, plants may adopt labor-intensive production techniques which are complementary to the low-skilled workers. This tendency of firms to make technological adjustments to complement the skill level of workers is also demonstrated in a paper by Acemoglu (1998). The study used a model of directed technical change to show that technological progress complements the skill level of the workforce. If the proportion of skilled workers is larger, there would be a faster pace of technological advancement. The contrary is true when the labor market is dominated by unskilled workers. A recent study by Thangavelu (2010) on Singapore's manufacturing sector found that the influx of foreign workers and capital investment decisions of firms are negatively correlated. Foreign workers are more productive if firms utilize less capital and technology intensive investments. Therefore, firms in Singapore's manufacturing sector have tended to adopt labor-intensive technologies. Ultimately, the overall effect of immigration on technological progress would depend on the characteristics of immigrant labor and the absorptive capacity of the receiving economy.

2.3 Productivity

Similar to the impacts on technology adoption, immigrants can exert either an upward or downward pressure on labor productivity. However, most empirical studies tend to find a negative impact of immigration on productivity, as the migrant populations examined are disproportionately composed of low-skilled workers. In a panel study of 24 OECD countries, Lull (2008) found that immigration had adverse effects on productivity, as each migrant worker is estimated to be only two third as efficient as a native worker. Kangasniemi et al. (2008) also found a negative impact of immigration on productivity in a comparative study of Spain and the UK. By decomposing the impact of migrant workers into quality and quantity effects, it is found that immigration in both Spain and the UK has overall negative effects on productivity. However, they find that the negative productivity effects of migrant workers in the UK is relatively smaller, hinting that the negative impact of immigration on productivity will decrease over time as an economy develops and immigration policy evolves. The adverse effects of migrant workers on productivity can also manifest itself in the rate of productivity growth. Using state-level data, Quispe-Agnoli and Zavodny (2002) found that in states which absorbed a larger share of immigrants in the 1980s, labor productivity experienced a relatively slower increase in both low-skill and high-skill industries.

Contrary to the findings above, a study of migration in 14 OECD countries from 1980 to 2005 by Ortega and Peri (2009) revealed no significant impact of immigration on total factor productivity (TFP). Immigration increased employment one-to-one, and investment adjusted rapidly to the increase in workers, leaving the capital intensity of production unchanged. In a recent study of Israeli manufacturing firms, Paserman (2009) found no correlation between the share of immigrants employed and firm productivity. However, when the analysis was conducted according to the level of industrial technology, share of immigrants was found to be negatively correlated with productivity in low-tech industries. The increase in the pool of unskilled workers due to immigration raises the incentives of firms to adopt labor-intensive production methods, which are both cheaper and complementary to the unskilled workforce. Clearly, labor productivity and technology adoption are intricately correlated. The presence of a large proportion of unskilled workers discourages technology adoption, which results in decreasing capital investments. With a lower capital intensity of production, labor productivity inevitably falls.

3. International Labour Mobility in Asia

The inflow and outflow of migrant stock of selected countries in Asia is given at Table 1. The inter-region migration matrix is created using data from the updated bilateral migration matrix in World Bank (2010). It contains data from 212 countries, compiled from various sources such as national censuses and national statistical bureaus.[4]

[4] The original bilateral migration matrix is developed by Ratha and Shaw (2007).

Table 1: Inflow and Outflow of Migrant Stock in Asia at 2010

Destination Country	Outflow	Inflow
Brunei	24,343	148,123
Cambodia	350,485	335,829
China	8,344,726	685,775
Hong Kong	718,990	2,741,800
India	11,360,823	5,436,012
Indonesia	2,504,297	122,908
Japan	771,246	2,176,219
Korea	2,077,730	534,817
Malaysia	1,481,202	2,357,602
The Philippines	4,275,612	435,423
Singapore	297,234	1,966,865
Thailand	811,123	1,157,263
Vietnam	2,226,401	69,307

Source: World Bank

Table 2: Sources of Migrant Inflow by Region to Selected Asian Countries as of 2010(%)

	Source by Region						
	East Asia	South East Asia	South Asia	Europe	Australia& New Zealand	North America	Others
Brunei	2.9	81.4	10.0	3.2	0.5	0.2	1.8
Cambodia	2.6	95.5	0.3	0.6	0.2	0.3	0.6
Hong Kong	83.7	0.0	0.0	0.0	0.0	0.0	16.3
India	0.5	1.3	92.4	0.2	0.0	0.1	5.6
Japan	55.8	15.3	2.4	2.4	0.7	2.9	20.6
Korea	55.0	21.9	3.1	1.1	0.7	8.0	10.2
Malaysia	6.2	79.9	10.4	0.7	0.4	0.0	2.5
Philippines	12.3	2.1	2.1	12.3	0.7	10.8	59.6
Singapore	25.4	59.1	10.2	0.0	0.0	0.6	4.6
Thailand	35.1	38.7	6.3	3.1	0.9	1.2	14.6
Indonesia	62.6	0.0	0.0	5.8	0.0	0.0	31.7

Source: World Bank

There is a clear trend that large countries of China and India are experiencing large outflow of labour of 8.3 million and 11.3 million respectively. Among the East Asian countries, other than China, Korea also tends to experience outflow of people around 2 million as of 2010. Across the South-East Asian countries, we also observe a different trend among the key ASEAN countries. Indonesia and the Philippines tend to experience outflow of migrants of nearly 2.5 million and 4.7 million respectively. This is not surprising as both Indonesia and Philippines are the key labour export countries in the region. The other emerging countries of Malaysia and Thailand also experience outflow of migrants of nearly 1.5 million and 0.8 million people. As a small-open economy, Singapore has an out migration of nearly 0.25 million as of 2010. We also observe key inflows of migrants in Hong Kong, India, Japan, Malaysia, Singapore and Thailand, which is much higher than the outflow of migrants. As compared to China, there is a large migrant inflow in India of nearly 5.5 million as of 2010, which might be indicating the reverse migration of Indian origin migrants back to India. For the small open economies of Hong Kong and Singapore, there is a larger inflow of migrants of nearly 2.7 million and 2 million as of 2010, which is much higher than migrant outflow. Increasing these small open economies are relying on skilled-migrants to drive their economic growth. The other ASEAN countries of Malaysia and Thailand are also relying on inflow of migrants to drive their economy. Malaysia has a migrant inflow of nearly 2.2 million and Thailand nearly 1.1 million as of 2010. Interestingly, we also observe large inflow of migrants into Japan of nearly 2.7 million.

The inflow of migrants by region is given at Table 2. It is interesting to observe that the most of the migrants are regional based migration. Japan, Hong Kong and Korea tend to experience greater inflow of migrants from the East Asian region. For example, the inflow of migrants to Japan is from Korea and China. Hong Kong experiences greater inflow from China and Macau. As of 2010, the key migrants to

Korea are from China. We also observe similar trend for India, where the major migrants are from the South Asian region. The key migrants into India are from Sri Lanka, Nepal and Bangladesh.

As contrast to the other regions, the South-East Asian countries tend to have different regional sources for their migrant inflows. Malaysia and Singapore still relies on South-East Asian region to supply their labour supply, where the region migrant inflow is nearly 80 percent and 60 percent respectively for Malaysia and Singapore. However, Singapore and Thailand also relies on the East Asian region and in particular on China for the migrant inflows, which accounts for nearly 25 percent and 35 percent respectively. Brunei and Cambodia also relies heavily on migrant inflows from the South-East region.

The key trends of regional migration could be mainly explained by the trade, production structure and culture within the region. Due to cross-border trading activities and also similar cultural base, there is greater flow of migration across the South-East Asian countries. Due to cross-border relationship in trade, Cambodia experiences greater inflow of migrants from Vietnam and Thailand. The inflow of migrants into Thailand is mainly from Lao, Myanmar, and Cambodia. The key factor that drives regional migration is the regional production network. Intra-regional trade within the region could be one of the key factors for driving regional migration.

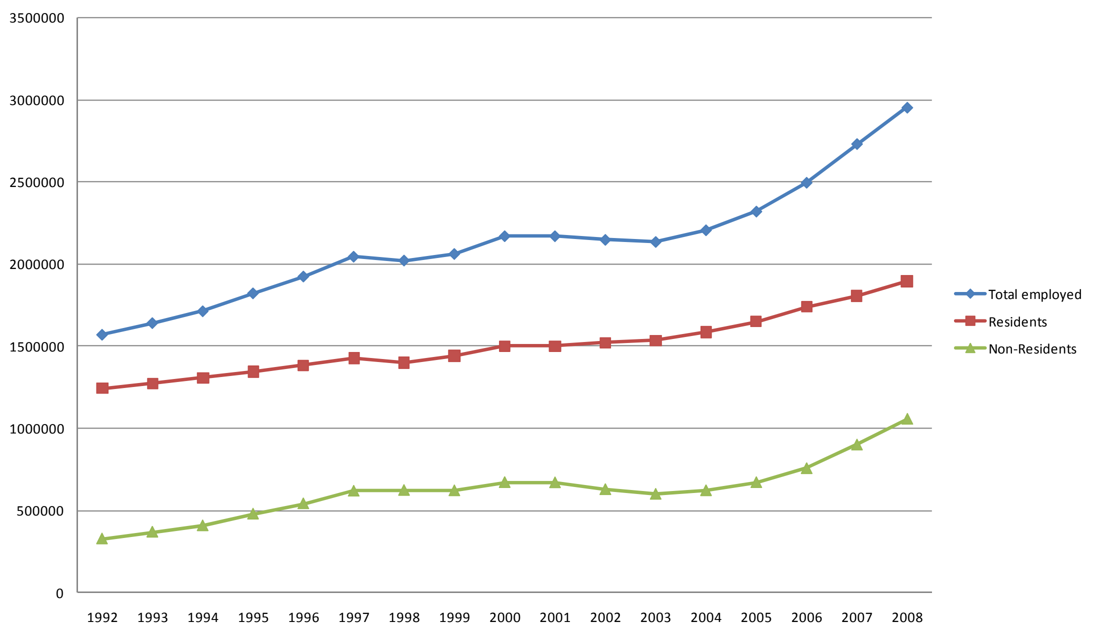
4. Foreign Manpower Policy in Singapore

Increasingly the Singapore economy is relying on foreign manpower to maintain competitiveness and economic growth in the economy. Foreign manpower is expected to fill the manpower shortage and also to maintain the cost competiveness of the domestic firms in global trade. Foreign manpower, both skilled and unskilled, serves dual purpose for the small open economy. Given that the Singapore economy is transiting to higher value-added activities, the Singapore economy faces strong storage of skilled domestic workforce to maintain the viability of high-end value-added industries. Thus, the skilled foreign workers are expected to augment domestic human capital and thus induce innovative activities in the domestic economy. This is expected to maintain competitiveness of exports of the local firms in high-end products.

In contrast, the economy also attracts low-skilled foreign workers to manage the "hollowing-out' effects of multinationals as they restructure their production structure towards low-cost countries such as India and China. Since the "hollowing-out" effects of multinational could create structural unemployment of local workers in the economy due to the dislocation of low-end production chain, the unskilled foreign workers are seen as one way to keep the cost of production down and manage the dislocation of multinationals in the domestic economy (see Chia, Thangavelu and Toh, 2004).

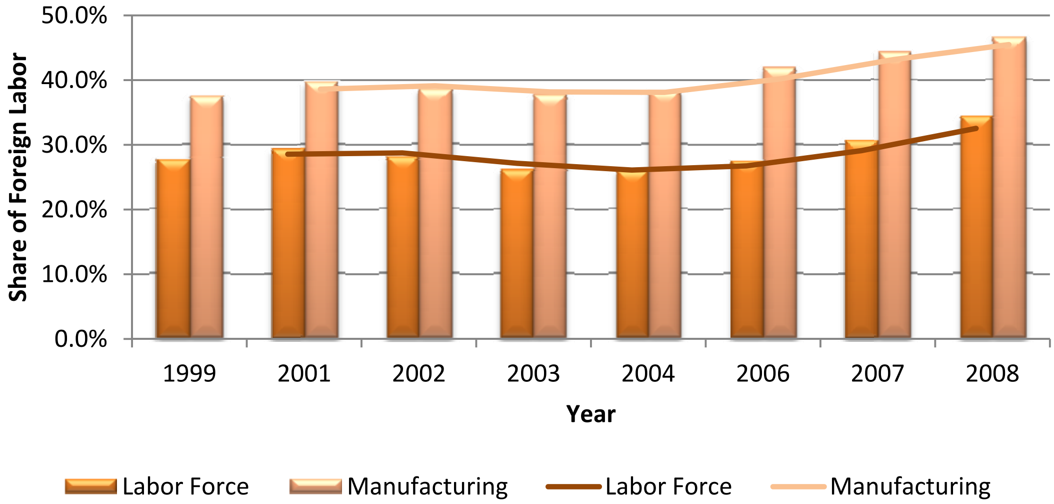
The aggregate trends of labour force by resident (Singapore citizens and permanent residents) and non-resident (foreign workers) are given in Figures 2 and 3. The total employment increased rapidly since 1992, where total employment doubled in the 2008 increasing from nearly 1.5 million in 1992 to around 3 million workers. The non-resident employment in the Singapore economy is also showing an upward trend since 1992. In 1992, resident employment accounted for nearly 79 percent of the total employment and non-residents were only around 20 percent share of total employment. By 2008, the share of non-residents increased to nearly 36 percent of the total employment (see also Labour Market, 2008, MRSD, MOM). The growth trends of residents and non-residents were also given in Figure 2. The non-resident employment is showing greater dynamics in the labour market as compared to the resident employment in the Singapore economy, growing at an annual rate of nearly 7.9 percent in 1992-2008. In contrast, from 1992 to 2008, the resident employment grew by only an average annual rate of 2.7 percent, thereby highlighting the labour constraints in the small-open economy. In fact, there was greater inflow of permanent immigrants in the economy in terms of permanent residents to augment the residents, as the growth rate of Singapore citizens is constrained by a falling fertility rate. From 1997 to 2006, the employment of permanent residents in the total employment grew at the rate of 8.4 percent as compared to 1.5 percent for Singapore citizens (see Employment of Singapore Citizens, Permanent Residents and Foreigners, 1997-2006, MRSD, MOM).

Figure 2: Total Employment of Resident and Non-Resident Workforce in Singapore (1992-2008)



Source: Ministry of Manpower, Singapore. Some years are extrapolated based on published data from "Employment of Singapore Citizens, Permanent Residents, and Foreigners: 1997-2006", MRSD paper no: 1/2008; "Employment Trend and Structure", MRSD paper no: 2/2004; "Manpower 2008", MRSD; "Manpower 2009", MRSD. Thus there might be rounding-off errors in the data. The above sample is only an approximation from 1992-1996.

FIGURE 3: SHARE OF FOREIGN LABOR IN THE LABOR FORCE AND THE MANUFACTURING SECTOR IN SINGAPORE, 1999 – 2008



Note: Data for 2000 and 2005 are not available as the Labor Force Survey was not conducted in those years.
Source: Singapore Yearbook of Manpower Statistics, 2010 (Ministry of Manpower, Singapore)

5. The Model and Key Results

Foreign workers have become an increasingly important component of the labour force in Singapore. While foreign workers are necessary to fill the manpower shortage and generate more economic activity, there have often been concerns raised about whether the influx of foreign workers has depressed the wages of local workers, particularly the low-skilled workers and the overall productivity of the economy.

However, the effects of migration on the equilibrium and dynamics of the labour market is quite complex given the characteristics of the migrants and current domestic economic conditions in the economy. In the long-run, in addition to augmenting aging labour force, the impact on the long-term growth of foreign workers depends on their productivity and hence on their skills and human capital. This will have a direct impact on innovative and technology adoption capability of domestic firms. Thus the average human capital of foreign workers will have long-term implications for the Singapore economy. In the short-run, inflow of foreign workers could resolve the cyclical fluctuations and short-term shortages of the labour market, thereby maintaining the competitiveness of the labour market.

In the current paper, we adopt the Drinkwater, Levine, Lotti and Pearlman's three-sector general equilibrium model with endogenous growth (2007) and calibrate to the Singapore economy. The paper models three major sectors in the Singapore economy: a labour-intensive service sector which is assumed to produce a homogenous good, and the value-added goes to our physical capital accumulation; a capital-intensive manufacturing sector which produces differentiated goods with growing varieties; and an innovative sector, which is assumed to be the engine of growth of the economy that conducts the necessary research activities for new product development. All sectors employ three factor inputs, namely the skilled workers, unskilled workers and physical capital. Since there is no closed-form solution to our general model, we will adopt a numerical method and narrow down our scope to the steady-state analysis. The full details of the three-sector general equilibrium model and the numerical solution for the steady-state values are given in the Annex.

We briefly summarize the various key parameters specified in our model to calibrate the Singapore economy. According to the Singapore Standard Industrial Classification (SSIC) 2005, wholesale & retail trade, hotel & restaurants, information and communications, financial and business services are together classified as service producing industries, we will assume the services provided to the consumers can be treated as a homogenous good for simplicity. The manufacturing, construction and utilities are classified as good producing industries by SSIC 2005. We assume that the development of new ideas in the innovation sector is not for direct consumption, but continuously drives product differentiation and environmental-friendly and cost-effective production techniques in the good producing industries. The innovation sector in the study consists of the chemical & petroleum, electrical, electronic, and precision & instrumental industry. The rest of the manufacturing industries are considered as manufacturing sector.

5.1. Simulation 1: Large Unskilled Workers and Low Growth

The parameters for our model are given in the Annex. The key parameters for the large unskilled workers in the economy are defined by the factor share of skilled and unskilled workers. The factor shares for unskilled and skilled workers are $s_{Ls} = 0.43$ and $s_{Hs} = 0.5$ in the services sector; $s_{Lm} = 0.5$ and $s_{Hm} = 0.4$ in the manufacturing sector and $s_{Li} = 0.47$ and $s_{Hi} = 0.38$ in the innovation sector. The high factor shares for unskilled workers (s_{Ls}, s_{Lm}, s_{Li}) reflect high level of unskilled workers in these sectors. In particular, the high factor share for innovation sector (s_{Li}=0.47) reflects that large influx of unskilled foreign workers in chemical & petroleum, electrical, electronic, and precision & instrumental industries. The employment share in the pre-immigration state is taken as 0.45 for skilled workers and 0.55 for unskilled workers. The employment share of foreign immigrants is maintained at 0.40 in the post-immigration state.

The steady state set-up as specified in the Annex is used to obtain the numerical solutions for our model. Assuming uniform skill-composition in each sector, we will analyze the effect of an increase in the total factor share of the skilled immigrant workers on the growth rate, the size of the innovative sector and the changes in relative wage rates in the steady state, as well as to estimate the sign and magnitude of the immigration surplus in the Singapore economy. We will also explore the possible complementarities between skilled labor and physical as suggested by Hammermesh (1993). Given no empirical evidence of crowding-out effect of immigrants on the native employment by Hunt and Gauthier-Loiselle (2008), Peri (2009), as well as Ortega and Peri (2009), and the initial assumption that immigrants do not alter the capital stock immediately after gaining entry, we will keep the factor shares of the native labour and physical capital constant. Hence the increase in the fraction of skilled immigrants in the simulation is achieved by decreasing that of the unskilled immigrants and vice versa.

The simulation results of the steady-state growth rate with increasing inflow of skilled immigrants (decrease in the share of unskilled foreign workers) are given in Figures 4 to 7 below.

From Figures 4 and 5, there are clear evident that there is a positive effect of the skilled immigrants on the steady-state growth rate of around 1.1% and it also increase the size of the innovative sector when their fraction within the total immigrant workforce is increased from 0 to 60%. The inflow of skilled immigrants relative to unskilled workers tends to encourage more research activities in the economy and hence promote long-term growth. However, the increase in skilled immigrants in the economy tend to increase the growth rate and size of the R&D sector at a diminishing rate, and both variables started to decline when the fraction of the skilled immigrants exceeds a threshold of 60%. The diminishing return is expected to set in once the reward from the complementarities between the physical capital and the skilled immigrants is fully exploited. The ‘crowding-out’ effect on the total physical capital causes the steady-state growth rate and the size of the innovative sector to decrease after reaching the threshold. The maximum percentage growth gain is achieved when the physical capital is fully exploited by the skilled workers in the economy, which corresponds to a 60% of the skilled among the immigrants.

FIGURE 4 STEADY STATE GROWTH RATE WITH HIGH UNSKILLED

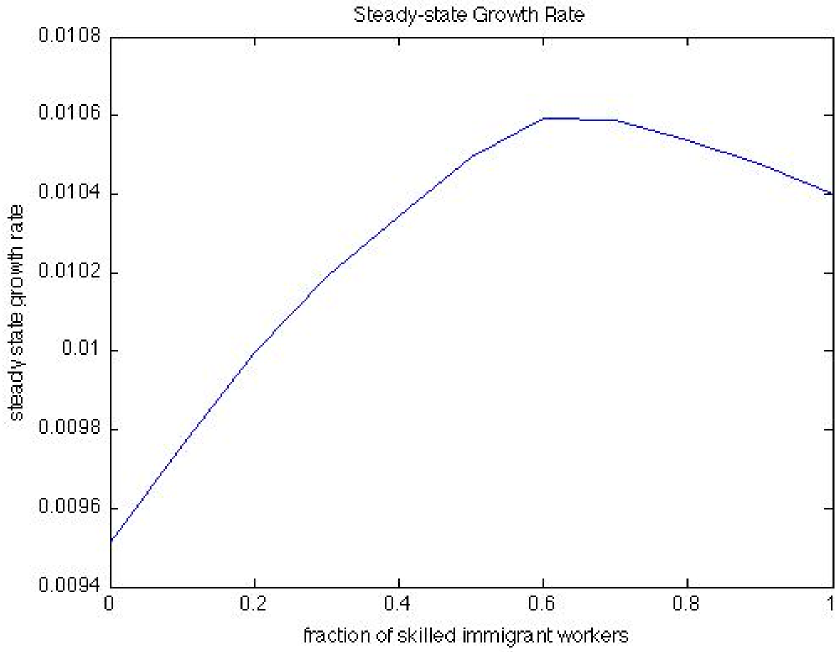
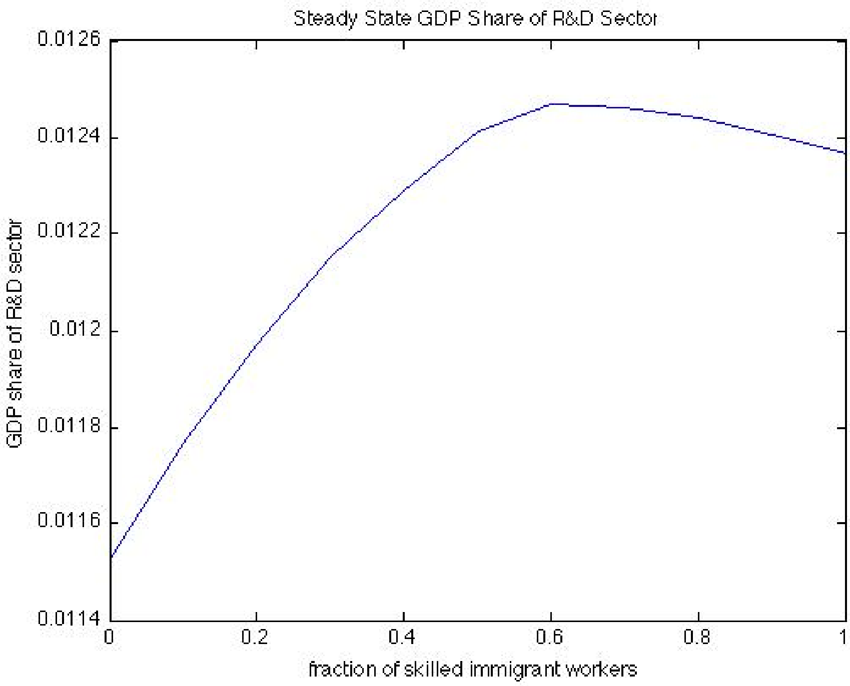


FIGURE 5 STEADY STATE GDP SHARE OF R&D SECTOR WITH HIGH UNSKILLED



The simulation results of the magnitude of the wage gap and immigration surplus for the Singapore economy for the above parameters are given in Figures 6 and 7 respectively. Figure 6 shows the relative wage rates for the skilled and unskilled workers in the economy following the immigration. When more skilled foreign workers enter the economy, the increase in total supply drives the skilled wages down and thereby narrows the wage gap between the skilled and unskilled workers. The results indicate that the wage gap between the two skill types is narrowed when the fraction of skilled immigrants is below 60%. However, the gap widens after reaching the threshold level of 60% of skilled immigrants. The widening of the wage gap with higher share of the skilled immigrants could be explained by the greater substitution of the skilled for unskilled workers. When the fraction of skilled immigrants exceeds 60% threshold, skilled workers become abundant in the economy and their wage rate decreases to a sufficiently low level. This enables the employers to seize the opportunity to substitute the relatively cheaper skilled human capital for the unskilled labour. This will increase the demand for skilled workers and drive their wages marginally higher. The resurgence in demand for skilled workers increases their wage rate accordingly, and the fall in demand for unskilled labour drives their wage rate to a lower level, thus creating a widening wage gap.

Based on Figure 7, immigration surplus (IS) for local workers differs by their respective skill types. The IS of skilled native worker remains positive and reaches its maximum of an equivalent permanent consumption increase of 0.80% when the immigrant workers are completely unskilled, while that of the unskilled remains negative and increases when the fraction of skilled immigrants is increased. Furthermore, the decrease in skilled IS and the increase in unskilled IS prior to the 60% threshold indicates a redistribution effect from the native skilled workers to the native unskilled workers, which comes from the narrowing of the wage gap, and vice versa for the opposite movement in IS when the fraction exceeds its 60% threshold. It is evident that the skilled immigrant workers have positive impact on the size of the immigration surplus and the unskilled exert negative forces when the fraction of skilled immigrants is held below 60%, and vice versa when the fraction is increased further. Table 3 below summarizes the estimated key values of IS for different groups in the Singapore economy, where F_s indicates the fraction of the skilled workers within the immigrant workforce.

TABLE 3: ESTIMATED KEY VALUES OF IS IN THE SINGAPORE ECONOMY

Skill Type	Immigration Surplus with Growth		
	$F_s = 0$	$F_S = 0.6$	$F_s = 1$
Skilled	0.80	0.030	0.18
Unskilled	-1.84	-0.056	-0.31
Representative	-1.03	-0.026	-0.13

FIGURE 6: STEADY STATE WAGE GAP WITH HIGH UNSKILLED

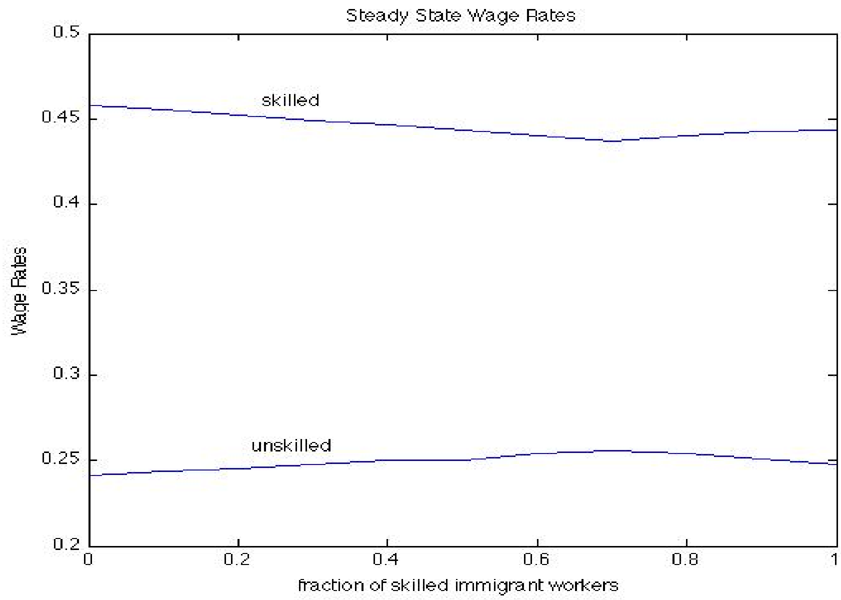
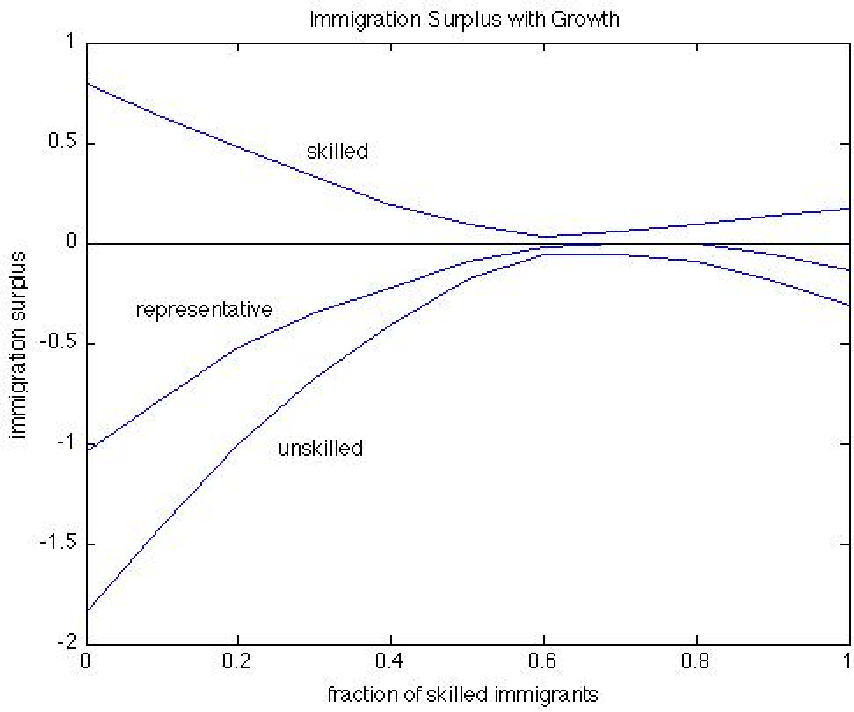


FIGURE 7: IMMIGRATION SURPLUS WITH GROWTH AND HIGH UNSKILLED

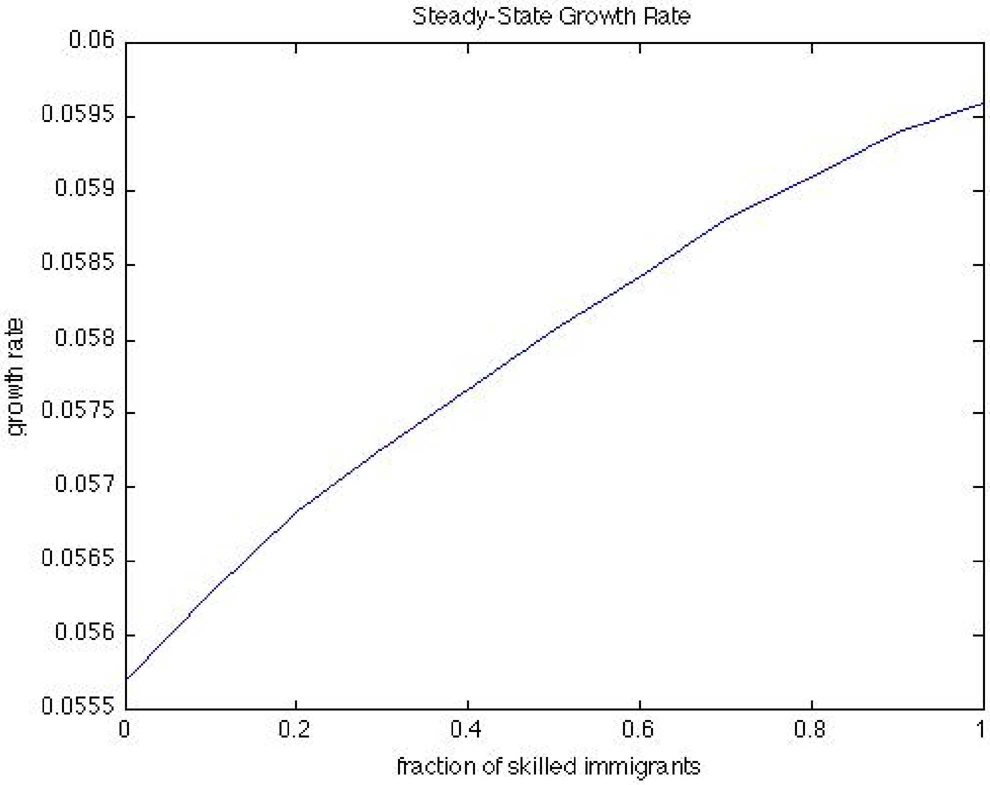


5.2 Simulation 1: Moderating Foreign Workers, Increasing Capital Intensity and High Growth

In the second simulation, we moderated the flow of foreign workers by maintaining the share foreign at 30 percent of the total labour force. The skilled employment share in the pre-immigration state is also taken to be higher at 0.55 and 0.45 for unskilled workers. This reflects the current government policy to increase the number of skilled workers in the economy and concurrently moderating the flow of unskilled foreign workers.

The factor shares for unskilled and skilled workers are $s_{Ls} = 0.14$ and $s_{Hs} = 0.46$ in the services sector; $s_{Lm} = 0.14$ and $s_{Hm} = 0.30$ in the manufacturing sector and $s_{Li} = 0.1$ and $s_{Hi} = 0.25$ in the innovation sector. The high factor shares for skilled workers (s_{Ls}, s_{Lm}, s_{Li}) reflect high level of skilled workers in these sectors. Further, we also allocated higher factor shares for capital for all the 3 sectors. The capital shares are $s_{Ks} = 0.4$, $s_{Km} = 0.55$, and $s_{Ki} = 0.65$ for services, manufacturing and innovation sectors respectively. This is in line with the current policy of increasing the capital accumulation in the key sectors. The simulation results for the moderating foreign workers with high capital intensity are given in Figures 8-10.

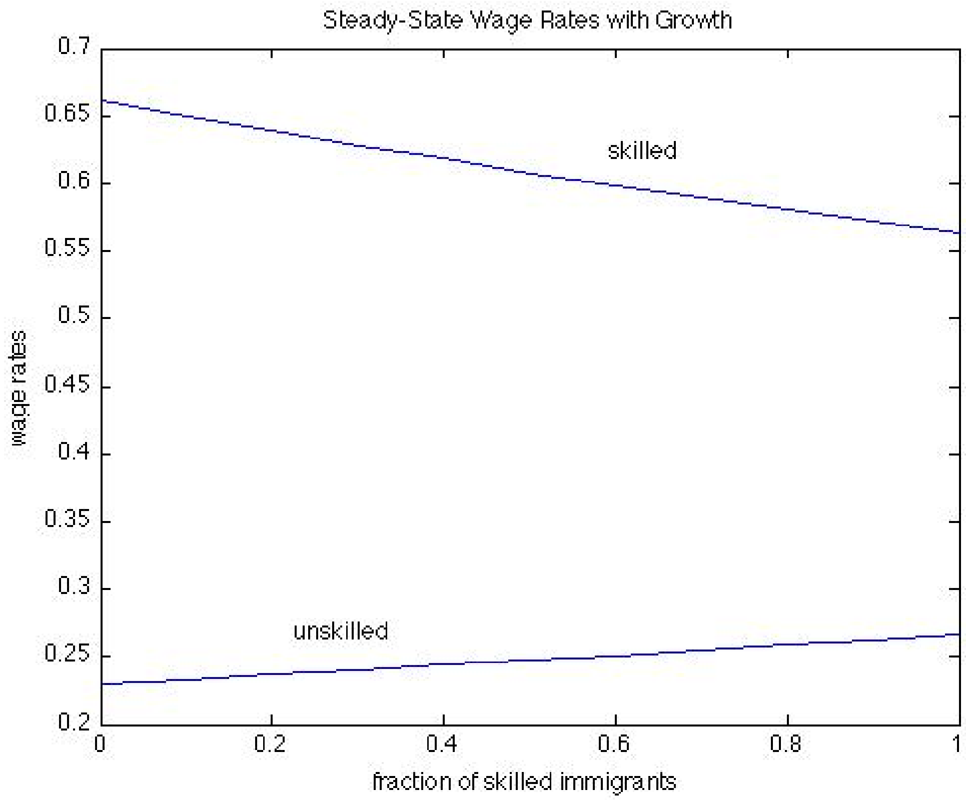
FIGURE 8: STEADY STATE GROWTH RATE WITH LOW UNSKILLED



It is interesting to observe that high share of skilled workers produce higher steady-state growth rate of nearly 5% and the economy also experience less diminishing returns due to the increasing share of skilled immigrants on the output growth and conversely on the innovative sector (see Figure 8). This result is mainly driven by the high share of capital accumulation (capital share) in the innovative sector and thus there is a greater complimentarity between skilled and capital investments, which is not fully exploited. The greater inflow of skilled immigrants tends to complement capital and increase the innovative activities in the domestic economy and thus leading to higher steady-state growth.

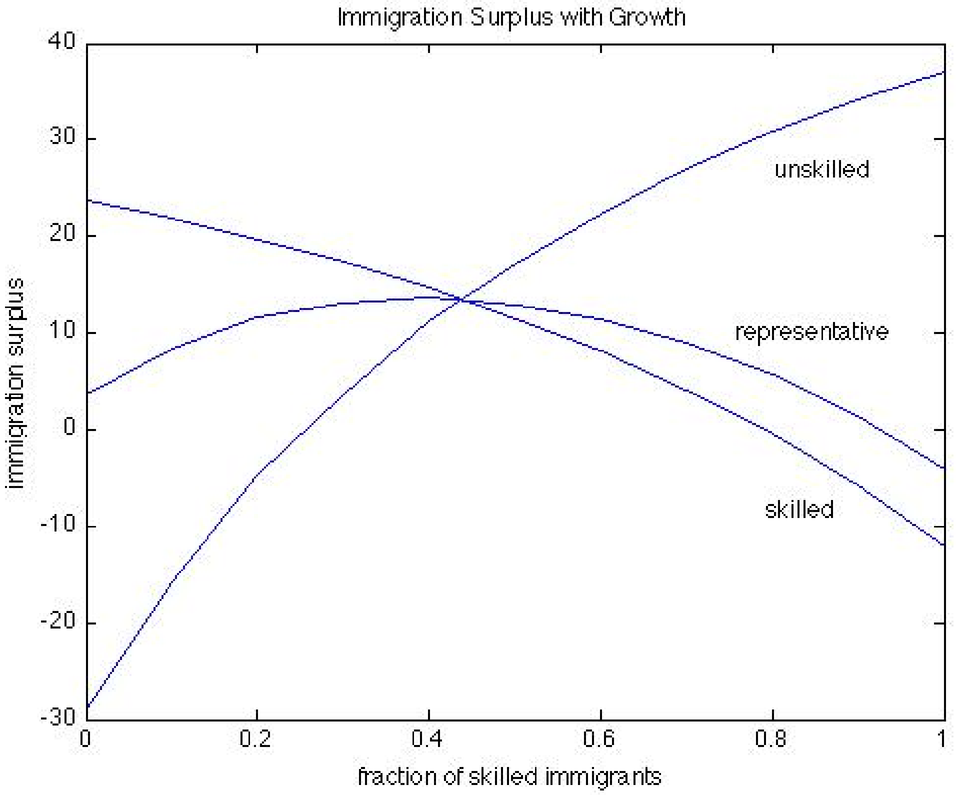
The simulation result of the wage gap is reflected in Figure 9. It is interesting to observe that the wage gap between the skilled and unskilled narrows as the foreign share is maintained at 40% of the workforce. This is mainly due to the increase supply of skilled workers in the economy due to the inflow of skilled immigrants and the reduction of unskilled foreign workers in the economy. We also observe that the factor shares of unskilled workers also increases moderately as their demand increase due to higher output growth.

FIGURE 9: STEADY STATE WAGE GAP WITH LOW UNSKILLED



The simulation result of the immigration surplus in a high capital accumulation with moderate foreign worker is given in Figure 10. As compared to the simulation with high share of unskilled workers, it is interesting to observe that the IS of unskilled workers tends to increase with large flow of skilled immigrants in the economy. This is in line with the rising demand for the unskilled workers as the innovative increases with higher manufacturing and services activities, thereby increases their wage rates. The IS for skilled workers decline as the share of skilled foreign workers increase, which is mainly due to the decline in their wage as the supply of skilled workers increases.

FIGURE 10: IMMIGRATION SURPLUS WITH GROWTH AND LOW UNSKILLED



6. Policy Conclusion

The result of the model indicates that skilled immigrants do exert positive effect on the indigenous economy, but at a diminishing rate. Skilled immigrants tend to encourage more research activities in the economy and hence promote long-term growth. We also observed that the diminishing returns set in when the reward from the complementarity effect between the physical capital and the skilled immigrants is fully exploited.

The simulation results also highlights that moderating foreign workers at 40% of the workforce with high capital intensity produces positive output growth. In this equilibrium, we also observe higher steady-state growth with higher share of skilled foreign workers. The rising share of skilled foreign workers reduces the skilled wage rate and also the wage gap between the skilled and unskilled in the economy.

The results also indicate that the positive impact of immigrants and in particular the skilled immigrants depend on the innovative activities in the economy. In particular, there is diminishing return from having additional skilled foreign workers in the economy, for a given level of capital stock in the economy. This indicates that there is a threshold level of skilled immigrants that will have positive impact on the innovative sector and growth of the economy. This is very crucial as the Singapore economy moderates its flow of foreign workers and increases its competitiveness in the global economy.

Investments in local human capital are also vital for the long term growth of Singapore's economy. In a globalized environment, workers have to constantly upgrade their skills to stay relevant. At present, most training programmes are designed for and targeted at low-skilled local workers. This enables them to improve their productivity levels and command higher wages, thereby reducing wage inequality. With the shift towards higher-value added activities, Singapore will need to implement general training schemes for the entire workforce. Constant re-training and skills upgrading is necessary to meet the rapidly evolving demands of the labor market. These investments in local human capital will grant productivity gains, thereby improving the long term growth potential of the Singapore economy.

This study could be extended in several directions. The impact of training and accumulation of human capital through education on output growth could be explored with immigrant workforce. The paper could also explore the labour market policies such as levy, quota, structural unemployment, Workfare Income Supplementation, Job Credits and aging issues on steady-state growth and welfare.

We also need to quantify the impact of immigrants on other ASEAN countries based on the general equilibrium model. Recent study by Chia (2006) highlights the impacts of migrants are different for labour-exporting and labour importing countries. In particular, the welfare effects of outflow of skilled migrants out of labour-exporting countries such as the Philippines and unskilled migrants Indonesia could affect the productivity of local workforce and create structural changes in the domestic economy. The paper by Chia (2006) also highlights the importance of the interaction between trade and international labour mobility. The paper also did not clearly modelled the institutional framework and the impact of free trade agreements and this could be included in the future study.

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<u>ANNEX 1</u>

THE MODEL

We will follow DLLP's (2007) three-sector general equilibrium model to study the effects of immigrants on the economy. The DLLP model assumes that the natives own all the capital and thus immigrants do not augment the capital stock immediately after gaining entry. In the Singapore context, we consider three sectors: a labor-intensive service sector (s) produces a homogenous good; a capital-intensive manufacturing sector (m) produces differentiated goods with growing varieties and a high-technology innovative sector (i), conducts the necessary research activities for new product development. All sectors employ three factors of inputs: skilled labour (H), unskilled labour (L) and physical capital (K), which is accumulated from the value-added in the service sector. Given the respective nature of the final products, we assume a competitive market structure for the service sector and a monopolistic one for the manufacturing sector. The labour markets are assumed to clear at the equilibrium wages, skilled wage (w_H) and unskilled wage (w_L) respectively.

The Demand Side

Assume that there are two types of workers present in the indigenous economy, the skilled and unskilled supplying fixed quantities of labour and each choosing to maximize a Cobb-Douglas form of inter-temporal utility function given by,

$$U_l(t) = \int_t^{\infty} e^{-\rho(\tau-t)} \left\{ \frac{\left[(C_{ml})^{\theta_m} (C_{sl})^{\theta_s} \right]^{1-1/\sigma} - 1}{1-1/\sigma} \right\} d\tau; \quad \sum_{i=m,s} \theta_i = 1, \ \sigma \neq 1;$$

where ρ is the subjective rate of time preference[5], σ is the elasticity of inter-temporal substitution in any two periods, measures an individual's willingness to substitute current consumption for future consumption, C_{sl} indicates the total amount of services consumed by type l workers, and C_{ml} represents a real consumption index for the manufacturing goods corresponding to type l workers. Given the monopolistic market structure in the manufacturing sector, we assume the real consumption index is given as follows:

(2) $$C_{ml} = \left[\int_0^n (x_{jl})^{\alpha} \, dj \right]^{1/\alpha}; \quad 0 < \alpha < 1$$

where n is the total number of manufactured goods available to the consumers, $\varepsilon = 1/(1-\alpha)$ is the elasticity of substitution between varieties and x_{jl} is the total real consumption level of variety j by type l workers.

The consumers' optimization problem consists of two stages. In the first stage, total consumption in the current period is maximized over the amount of services and manufacturing goods, given total nominal household expenditure for each type of household as, $C_l = \int_0^n \left(p_{mj} x_{jl} \right) dj + p_s C_{sl}$.

[5] $\rho \geq 0$, the two limiting cases are: while the future is completely ignored when $\rho \to \infty$, and we do not discount the future consumption if $\rho = 0$.

Similarly, by treating each variety as a separate entity, the individual demand function for the manufactured goods of type l workers is obtained as,

(3) $$x_{ql} = \frac{\theta_m C_l p_{mq}^{-\varepsilon}}{\int_0^n p_{mj}^{1-\varepsilon}\, dj}; \quad q \in [0, n].$$

Aggregating over the available varieties, the total demand for each variety is given as,

(4) $$x_q = x_{Lq} + x_{Hq} = \frac{\theta_m C p_{mq}^{-\varepsilon}}{\int_0^n p_{mj}^{1-\varepsilon}\, dj}; \quad q \in [0, n],$$

where $C = C_L + C_H$ gives the total nominal expenditure.

In the second stage, the consumers' optimization problem is extended to an infinite horizon. Consider the net assets held by both household types as a summation of the total value of domestic physical capital and the market value of blueprints in the innovative sector[6], i.e.

(5) $$A = A_L + A_H = \int_0^n v_j\, dj + p_s K,$$

where v_j represents the individual market value for the variety j.

Given the no-arbitrage rule in the financial market, the assets earn the risk-free interest rate r, the budget constraints for both household types are thus given as,

(6) $$\dot{A}_l = rA_l + w_l l - C_l; \qquad l = L, H.$$

Consumers seek to maximize their inter-temporal utility, subject to their optimal demand functions, and their budget constraints. The standard dynamic solution yield the following,

(7) $$\frac{\dot{C}_l}{C_l} = (1-\sigma)\frac{\dot{P}}{P} + \sigma(r-\rho); \quad l = L, H,$$

where $P = (P_m)^{\theta_m} p_s^{\theta_s}$ is the total consumption price index. Aggregating over the two types of workers, we have,

(8) $$\frac{\dot{C}}{C} = (1-\sigma)\frac{\dot{P}}{P} + \sigma(r-\rho),$$

and the corresponding budget constraint is given by,

(9) $$\dot{A} = rA + w_L L + w_H H - C.$$

[6] Assume that the total number of blueprints available at any time t is equal to the total number of varieties in the manufacturing sector.

In a symmetric equilibrium, where all manufacturing firms face identical demand and production costs, equating all individual prices to p_m and quantities demanded to x and hence the market values to v we have,

(10) $$A = A_L + A_H = nv + p_s K .$$

The Supply Side

The Service Sector

Assume the production process in the service sector employs the three factor inputs and follows a two-level nested CES production function[7] given by,

(12) $$S = T_s \left\{ \gamma_{1s} L_s^{\eta_s} + (1-\gamma_{1s}) \left[\gamma_{2s} H_s^{\xi_s} + (1-\gamma_{2s}) K_s^{\xi_s} \right]^{\frac{\eta_s}{\xi_s}} \right\}^{\frac{1}{\eta_s}}$$

where T_s is the total factor productivity (TFP) of the service sector, γ_{1s}, $(1-\gamma_{1s})\gamma_{2s}$ and $(1-\gamma_{1s})(1-\gamma_{2s})$ are the factor shares of the unskilled workers, skilled workers and physical capital respectively. The empirical evidence by Hammermesh (1993) suggests the complementarities between the skilled labour and physical capital when $\xi_y < 0$.

Let the capital depreciation rate be δ, assuming the accumulated capital earns the risk-free rate r, the rental price of the physical capital is given by $R = p_s \left(r + \delta - \frac{\dot{p}_s}{p_s} \right)$. The representative firm's problem[8] is to minimize the total cost function $\Phi_s = w_H H_s + w_L L_s + RK_s$ for a given level of output S, as specified in the above production function, which again can be solved using standard dynamic programming framework. The respective unit factor requirements ι_{Ls}, ι_{Hs} and ι_{Ks} of the three inputs can be obtained by applying Shepherd's lemma to the minimum unit cost function $\phi_s(w_L, w_H, R)$.

Given the homogenous nature of the product, we assume a competitive market structure for the service sector, thus, it follows that the price of the product equals its marginal cost,

(13) $$p_s = \phi_s(w_L, w_H, R)$$

The Manufacturing Sector

Assuming there are n manufacturing firms in the economy, each produces one particular good and follows a nested CES production function analogous to equation (12) as follows,

[7] The general CES production function will collapse to the Cobb-Douglas form $Y = T_s L^{\gamma_{1s}} H^{\gamma_{2s}(1-\gamma_{1s})} K^{(1-\gamma_{1s})(1-\gamma_{2s})}$ when both η_s and ξ_s tend to zero.

[8] Detailed derivation can be found in Appendix A.II.

(14) $$x_q = T_m \left\{ \gamma_{1m} L_{mq}^{\eta_m} + (1-\gamma_{1m}) \left[\gamma_{2m} H_{mq}^{\xi_m} + (1-\gamma_{2m}) K_{mq}^{\xi_m} \right]^{\frac{\eta_m}{\xi_m}} \right\}^{\frac{1}{\eta_m}}; \quad q \in [0,n]$$

where the parameters T_m, γ_{1m}, γ_{2m} are similarly defined as those in the service sector, η_m and ξ_m are the industry-wide substitution parameters. The minimum unit cost function $\phi_m(w_L, w_H, R)$ can be derived analogously as before.

In a symmetric equilibrium, where $p_{mq} = p_m$ for all $q \in [0,n]$, all firms are identical. Thus we arrive at the following equilibrium:

(15) $$P_m = n^{1/(1-\varepsilon)} p_m;$$

(16) $$p_m = \phi_m / \alpha;$$

(17) $$x = \frac{\theta_m C p_m^{-\varepsilon}}{P_m^{1-\varepsilon}};$$

(18) $$\pi = (1-\alpha) p_m x.$$

where x denotes the identical quantity demanded for each variety, thus the total quantity demanded for the manufacturing goods is given by nx, denote this quantity by X, and π is the identical profit level for each firm in the sector. Since the elasticity of substitution, ε, is greater than unity[9], the manufacturing price index P_m is a decreasing function of the number of varieties available.

The Innovative Sector

Similarly, we set out the innovative sector by first assuming the production technology of introducing new varieties, including both new inventions and upgrades on the existing products, follows a two-level nested CES function,

(19) $$\dot{n} = T_i \Lambda \left\{ \gamma_{1i} L_i^{\eta_i} + (1-\gamma_{1i}) \left[\gamma_{2i} H_i^{\xi_i} + (1-\gamma_{2i}) K_i^{\xi_i} \right]^{\frac{\eta_i}{\xi_i}} \right\}^{\frac{1}{\eta_i}}; \quad q \in [0,n]$$

where the parameters are similarly defined as in the service and manufacturing sector, and the dot over n indicates the increment of varieties over time. The unit cost function and factor requirements can be calculated analogously to the other two sectors. We follow DLLP's (2003) construct of the innovative capital and define it as the density of the available number of varieties across the entire working population, which is given by $\Lambda = n / N$[10]. In this way, the amount of innovation capital is independent of the absolute number of varieties available, and according to Li (2000), the scale effect of the workforce size on the growth rate is eliminated as well.

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[9] Since $\varepsilon = 1/(1-\alpha)$ and $0 < \alpha < 1$.

[10] N is defined as $N = L + H$, which is normalized to unity in the pre-migration state.

The Financial Market

As mentioned earlier, the market value of a typical piece of innovation is denoted by v, the zero NPV rule requires this value to be equated with its unit cost, i.e.

(20) $$v = \frac{\phi_i(w_L, w_H, R)}{\Lambda}.$$

Under the usual no-arbitrage condition in the financial market, both types of workers, as shareholders, earn the risk free rate of return, which equals to the sum of dividend gains and capital gains, i.e.

(21) $$r = \pi / v + \dot{v} / v.$$

The Market Clearing Conditions

Equating the corresponding demand and supply in the service and manufacturing sector, we arrive at the following market clearing conditions for the outputs in the economy,

(22) $$S = C_s + \delta K + \dot{K}$$

(23) $$p_m X = P_m C_m$$

Given exogenous endowment levels of the labor supply, L and H, the model specification is then completed with the equilibrium conditions for both labor markets and the capital market,

(24) $$\begin{pmatrix} L \\ H \\ K \end{pmatrix} = \begin{pmatrix} \iota_{Li} / \Lambda & \iota_{Lm} & \iota_{Ls} \\ \iota_{Hi} / \Lambda & \iota_{Hm} & \iota_{Hs} \\ \iota_{Ki} / \Lambda & \iota_{Km} & \iota_{Ks} \end{pmatrix} \begin{pmatrix} \dot{n} \\ X \\ Y \end{pmatrix}$$

where ι_{bd}, $b = L, H, K;\ d = i, m, s$ are the respective unit factor requirements of the three factor inputs in the three sectors.

Welfare-Based Immigration Surplus

The steady-state welfare of the indigenous workers resulting from immigration is undertaken by comparing the prior and posterior steady-state welfare of the indigenous workers resulting from immigration. Since the consumption level depends on return on net assets and labour income for both skill types, we shall first analyze the asset accumulation process in the post-immigration era. Taking immigrant workers into account, the two types of labour are redefined as,

(25) $$L = N_L + M_L; \quad H = N_H + M_H;$$

where N_l, M_l, $l = L, H$ denote the number of native and immigrant workers for both skill types.

We will assume no skill differentials to exist between the natives and immigrants within each skill group, i.e. there is perfect substitutability between the native and the immigrant workers, and there is no discrimination against the immigrants in the indigenous labor market. We will assume immigrants do not bring physical capital into the economy, and they will accumulate net assets once they settle down in the domestic economy. The household budget constraints for natives and immigrants are given by,

(26) $$\dot{A}^N = rA^N + w_L N_L + w_H N_H - C^N ,$$

(27) $$\dot{A}^M = rA^M + w_L (L - N_L) + w_H (H - N_H) - C^M ,$$

where the superscripts $p = N, M$ denote native and immigrant respectively. Given $A = A_L + A_H = A_L^N + A_L^M + A_H^N + A_H^M$ and $C = C_L + C_H = C_L^N + C_L^M + C_H^N + C_H^M$, we have the aggregate household budget constraint,

(28) $$\dot{A} = rA + w_L L + w_H H - C ,$$

which takes the same form as in the pre-migration stage. Thus under our assumptions the only impact on the indigenous economy comes from the augmentation of the labor supply. We now consider the welfare separately by decomposing the net assets into the four different types of workers.

Immediately after receiving the immigration influx, the total assets in the economy remains at a given level defined by[11] $\bar{A} = \overline{nv} + \bar{p}_s \bar{K} = \bar{N}\phi_i + \bar{p}_s \bar{K}$. It then moves to a new steady state value of $A = N\phi_i + p_s K$ with settlement of new immigrants. Define the total migration rate m as the proportion of both skilled and unskilled immigrants to the indigenous workforce, i.e. $m = \frac{M_L + M_H}{\bar{N}}$, we can now express the total population after immigration as $N = (1+m)\bar{N}$. Though the immigrants do not alter the physical capital stock in the economy when they first enter the country, they do contribute to the subsequent accumulation and hence have a share in it. Assume the share of the newly accumulated physical capital is distributed proportional to the size of the total workforce, the total share of physical capital for immigrant and native workers are given by $\frac{mp_s}{1+m}(K - \bar{K})$ and $\frac{p_s(m\bar{K} + K)}{1+m}$ in the post-migration era. The change of share values of new ideas and inventions differ from the accumulation of physical capital, we assume that in the new steady state with immigration, the shares owned by native and immigrant workers are divided according to their respective population sizes: where $\bar{N}\phi_i$ is owned by the natives and $m\bar{N}\phi_i$ is owned by the immigrants.

[11] Where $N = N_L + N_H$ is the total size of working population in the pre-migration era.

The sum of equity and physical capital gives us the total net assets in the post-immigration era for the native workers and it is given as,

(29) $$A^N = \bar{N}\phi_i + \frac{p_s(m\bar{K}+K)}{1+m}$$

We can then divide the total net assets owned by the natives in the pre- and post-immigration steady state among the native skilled and unskilled workers, by assigning weights according to their labour income shares as,

(30) $$\bar{A}_l = \frac{\bar{w}_l N_l}{\bar{w}_L N_L + \bar{w}_H N_H}\bar{A},$$

(31) $$A_l^N = \frac{w_l N_l}{w_L N_L + w_H N_H}A^N; \quad l = L, H .$$

Once we have the steady-state values of the labour income and net assets for both skill types, we can proceed to the welfare calculations. The nominal consumption levels before and after immigration influx for both groups are given as,

(32) $$\bar{C}_l = \bar{r}\bar{A}_l + \bar{w}_l N_l,$$

(33) $$C_l^N = rA_l^N + w_l N_l; \quad l = L, H .$$

Since our calculation of the immigration surplus will be based on the change of steady-state welfare levels in the pre- and post-immigration era, we first calculate the steady-state welfare using the Cobb-Douglas utility function of the native workforce defined earlier. Assume in the post-immigration era, the economy reaches its new steady state at time T; the steady-state welfare value is obtained by changing the lower bound of the infinite-horizon inter-temporal utility function from t to T and calculating the resulting integral, which is given as follows[12],

(34) $$\begin{aligned} U_l^N &= \int_T^\infty e^{-\rho(\tau-T)} \left\{ \frac{\left[\left(C_{ml}^N\right)^{\theta_m} \left(C_{yl}^N\right)^{\theta_y} \right]^{1-1/\sigma} - 1}{1-1/\sigma} \right\} d\tau \qquad l = L, H \\ &= \frac{1}{1-1/\sigma}\left[\frac{(\theta_m^{\theta_m}\theta_y^{\theta_y})^{1-1/\sigma}(C_l^N/\tilde{P})^{1-1/\sigma} n(T)^{\theta_m(1-1/\sigma)/(\varepsilon-1)}}{\rho - \theta_m(1-1/\sigma)g/(\varepsilon-1)} - \frac{1}{\rho} \right] \\ &= U_l^N(C_l^N, n(T), g) \end{aligned}$$

[12] Detailed derivations can be found in the mathematical appendix.

where $\tilde{P} = p_m^{\theta_m} p_s^{\theta_s}$, the growth rate of varieties, $\dot{n}/n$, is at its steady state value of g, the particular solution of this differential equation, $n(t) = n(T)e^{g(t-T)}$, is used in the above derivation. In the absence of immigration, the steady-state welfare level at time T is obtained by substituting the corresponding nominal consumption level, number of varieties and the growth rate into the above expression, i.e. $U_l^N(\bar{C}_l, \bar{n}(T), \bar{g})$. In order to use our numerical solutions for the steady-state variables, we define our measure of immigration surplus in terms of an equivalent permanent consumption change as follows,

$$
\text{(35)} \qquad \begin{aligned} Immigration\ Surplus &= \frac{U_l^N(C_l^N, \bar{n}, g) - U_l^N(\bar{C}_l, \bar{n}, \bar{g})}{\Delta U_l^N} \\ &= \frac{(C_l^N)^{1-1/\sigma} / \chi(g) - (\bar{C}_l)^{1-1/\sigma} / \chi(\bar{g})}{[(1.01\bar{C}_l)^{1-1/\sigma} - (\bar{C}_l)^{1-1/\sigma}] / \chi(\bar{g})}; \qquad l = L, H \end{aligned}
$$

where $\chi(y) = \rho - \theta_m (1 - 1/\sigma) y / (\varepsilon - 1)$, $y = \bar{g}, g$ are the pre- and post- immigration steady-state growth rates, ΔU_l^N is the change of welfare level as a result of 1% permanent change in the nominal consumption level in the pre-immigration era, $\bar{n}$ is the number of varieties, which is assumed to be fixed in the pre- and post-immigration steady states so that the size of immigration surplus does not depend on the absolute number of varieties available in the economy. With calibrated parameters and numerical solutions from the earlier steady-state set-up of the model, we can indeed estimate the sign and magnitude of immigration surplus of the Singapore economy.

ANNEX 2

Calibration

After constructing the three-sector general equilibrium model and setting up the numerical solution for the steady-state values, we now proceed to calibrate the various parameters specified in our model to the Singapore context and try to analyze the potential impact of immigration on the Singapore economy in the long run.

The first step requires us to identify the classifications of the service and manufacturing sector in the Singapore economy. According to the Singapore Standard Industrial Classification (SSIC) 2005, wholesale & retail trade, hotel & restaurants, information and communications, financial and business services are together classified as service producing industries, we will assume the services provided to the consumers can be treated as a homogenous good for simplicity. The manufacturing, construction and utilities are classified as good producing industries by SSIC 2005. We assume that the development of new ideas in the innovation sector is not for direct consumption, but continuously drives product differentiation and environmental-friendly and cost-effective production techniques in the good producing industries.

Next we classify the skilled and unskilled immigrants according to the type of employment visa they are holding. Employment pass (EP) is granted to skilled immigrant workers with a recognized qualification and a minimum fixed monthly income of S$2500. S-Pass is designed for specialized semi-skilled immigrants, such as technicians, with a minimum education level of a diploma and a minimum fixed monthly income of S$1800. Work pass (WP)[13] is target at the unskilled immigrant workers with a maximum monthly income of S$1800. Thus we categorize EP and S-Pass holders as the skilled immigrants, and WP holders the unskilled immigrants in the Singapore economy.

On the demand side, utility weights θ_s and θ_m are estimated using the average proportion of annual private consumption expenditure devoted to services and goods producing industries from year 2005 to 2009[14], at the 2000 market prices, which gives us the values of 0.44 and 0.56 respectively. We follow DLLP's (2003) choice of inter-temporal elasticity of substitution, $\sigma = 0.4$, which is obtained from the range of 0.32 to 0.45 in Ogaki and Feinhart

[13] A dependency ceiling and a levy are imposed to protect the native workers.

[14] Data and calculation can be found in Appendix B.

(1998). The taste parameter of the differentiated manufacturing goods (α), is chosen to be consistent with DLLP (2003), at a value of 0.7, which is obtained from Keuschnigg and Kohler (1999).

On the supply side, we adopt the microeconomic approach of calibration upon obtaining the factor shares in each sector, in which the parameter values are consistent with the empirical data. The factor share parameters within each sector are obtained from the Singapore Yearbook of Manpower Statistics and Report on Labour Force in Singapore 2008, Ministry of Manpower. The factor shares for unskilled and skilled workers are $s_{Ls} = 0.43$ and $s_{Hs} = 0.5$ in the services sector; $s_{Lm} = 0.5$ and $s_{Hm} = 0.4$ in the manufacturing sector and $s_{Li} = 0.47$ and $s_{Hi} = 0.38$ in the innovation sector[15]. The factor share parameters within each sector, γ_{jl}, $j = 1, 2$; $l = s, m, i$, can now be calculated accordingly. Annual depreciation rate, δ, is chosen to be 0.1, which is consistent with DLLP (2003) and Canova et al (1994, 1996, 2000).

TABLE A.1: SUMMARY OF PARAMETER VALUES USED IN CALIBRATION

Parameters	Values	Sources
δ	0.1	Canova et al (1994, 1996, 2000)
α	0.7	Keuschnigg and Kohler (1999)
ρ	0.01	Levine, Lotti and Pearlman (2003)
ϕ_i	1.18	Levine, Lotti and Pearlman (2003)
σ	0.4	Ogaki and Reinhart (1998)
θ_s, $\theta_y = 1 - \theta_s$	0.44, 0.56	Calibrated
γ_{1s}, γ_{2s}	0.43, 0.88	Calibrated
γ_{1m}, γ_{2m}	0.5, 0.8	Calibrated
γ_{1i}, γ_{2i}	0.47, 0.72	Calibrated

[15] Innovation sector in our study consist of the chemical & petroleum industry, electrical industry, electronic industry, and precision and instrumental industry

TABLE A.2 PRIVATE CONSUMPTION EXPENDITURE

	2005	**2006**	**2007**	**2008**	**2009p**
		At 2000 Market Price (Million Dollars)			
TOTAL	81,666.5	85,146.4	90,358.9	92,457.2	91,996.1
Food & Non-Alcoholic Beverages	6,359.6	6,527.7	6,866.4	6,912.2	6,865.6
Alcoholic Beverages & Tobacco	1,302.4	1,271.4	1,390.8	1,452.0	1,543.1
Clothing & Footwear	2,811.0	2,982.6	3,234.5	3,219.4	3,051.2
Housing & Utilities	13,450.4	13,656.8	13,856.3	14,002.6	14,275.2
Furnishings, Household Equipment & Maintenance	5,441.2	5,673.1	6,339.5	6,618.8	6,445.5
Health	5,143.8	5,692.9	6,088.9	6,199.6	6,602.4
Transport	16,609.1	17,911.6	18,608.9	18,705.8	16,606.4
Communication	1,989.5	2,240.7	2,602.0	2,834.5	2,747.6
Recreation & Culture	9,122.6	9,772.5	10,455.9	10,708.4	10,331.8
Education	1,998.3	2,117.1	2,319.2	2,499.8	2,644.7
Restaurants & Hotels	6,226.8	6,606.6	6,979.4	7,077.0	6,888.4
Miscellaneous Goods & Services	9,366.7	9,483.1	10,250.7	10,428.4	10,162.0
Add: Residents' Expenditure Abroad	12,299.1	12,645.7	13,551.4	14,274.8	15,402.5
Less: Non-Residents' Expenditure Locally	10,454.0	11,435.4	12,185.0	12,476.1	11,570.3
Theta_m	0.45	0.44	0.44	0.44	0.44
Theta_s	0.55	0.56	0.56	0.56	0.56

Source: Singapore Department of Statistics

We classify the sum of private expenditure on food & non-alcoholic beverages, alcoholic beverages & tobacco, clothing & footwear, furnishings, household equipment & maintenance as the nominal consumptions for manufactured goods, and the sum of health, communication, recreation & culture, education, restaurants & hotels as the nominal consumptions for services, and divide housing & utilities, transport, miscellaneous goods & services, residents' expenditure abroad and non-residents' expenditure locally equally among the two categories. Using the data at 2000 market prices, we calculate the annual percentage of private consumption devoted to manufactured goods and services respectively. Taking the averages over the five-year period from 2005 to 2009, we arrive at the estimated values for parameter θ_m and θ_s, 0.44 and 0.56 respectively.