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Technological Knowledge Index and Macroeconomic Effects of Industrial Technology in Malaysia

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Abstract

This paper is intended to develop an index to measure the changes of technology in the manufacturing sector of Malaysia for the period 1980-2000. The index, namely the Technological Knowledge Index (TKI), had exhibited an upward trend and this suggests that the technology level of Malaysia had been improving gradually over the years. Nonetheless, it showed signs of weakening towards the end 1990s. Making use of the TKI, a research is conducted on the effects of industrial technology on the following eight Malaysian macroeconomic variables: consumer price index, total exports, gross national product, total imports, total investments, ratio of stock market capitalisation to gross domestic product, unemployment rate and average wage changes. The results show that industrial technology helps improving all these eight macroeconomic variables. Based on Johansen cointegration test, the variables of the equation models for total exports, gross national product, total imports and average wage changes are cointegrated. However, based on the small sample method of Pesaran et al.'s (2001), only the variables of the equation model for average wage changes are cointegrated.

Keywords: industrial technology, measurement, macroeconomic variables, effects

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1 Introduction

In the course of leapfrogging Malaysia into a knowledge-based economy, technology has become an increasingly important growth input. For the period 1990-2000, technical progress contributed 14.4 per cent to Malaysia's total factor productivity growth and the contribution is expected to increase over time. Thus, the efficacy and efficiency in technology utilisation is of paramount importance for Malaysia to successfully transform itself from a production economy to a knowledge economy (National Productivity Corporation, 2001).

In fact, technological innovation was first broached and researched in Schumpeter's pioneering work in the early 1920s. However, his contributions lack an analytical model and mathematical theory (Niehans, 1981). Since then, technology has been researched extensively by the Organisation of Economic Cooperation and Development (OECD) countries and they have come up with indices for measuring technology in recent years.

While such indices are equally important to developing countries, to date Malaysia has yet to invent one for measuring its own technology. It is likely due to the difficulties in choosing appropriate and commonly accepted variables for the index. Also, limited time series data has posed a problem for this kind of research to be carried out extensively in Malaysia. As no shoe that fits all sizes, it is improper for Malaysia to refer to these indices without certain caveats. Certainly, having such an index is badly required by the policy makers, technologists and industrial economists in Malaysia. Without it, they are unlikely to be able to objectively assessing the progress of the local technology development.

This paper attempts to develop an index, namely the Technological Knowledge Index (TKI), to measure the changes of technology in the manufacturing sector (termed industrial technology herein) of Malaysia for the period 1980-2000. Making use of the TKI, a study will then be conducted on the effects of industrial technology on the macroeconomic variables of Malaysia.

The organisation of this paper is as follows. The literature review is in Section 2 and it covers the nature, source and measurement of technology. Section 3 is the methodology of formulating the TKI and the study on the macroeconomic effects of industrial technology in Malaysia. All results are reported accordingly in Section 4. Finally, Section 5 provides the conclusion.

2 Literature Review

2.1 The Nature of Technology

The nature of technological knowledge may be termed as ‘complexity and cumulative learning’. Technology itself cannot be adequately described as easily transferable information, as it consists mainly of person and institution-embodied tacit knowledge which is transferred mainly through independent learning, personal contact and mobility. Part of the technological knowledge has, in fact, emerged from certain puzzles in interpreting the statistics on technological activities (Patel et al., 1995)

According to Patel et al. (1995), the barriers to imitation arise less from the withholding of useful and easily transferable knowledge, than from the considerable costs of accumulating tacit knowledge. It is limiting to consider that the only nature of the costs that manufacturing firms incur in acquiring new technology is to purchase new capital goods that embody the technology. The firms may, in fact, face a number of adaptation costs when introducing new technology. However, it is incorrect to assume that indigenous research and development (R&D) and the purchase of foreign technology are perfect substitutes for obtaining world best practice disembodied technology, as only the former enables the assimilation of new technology.

Most manufacturing firms, on average, spend at least three times more on development activities (i.e. designing, building and testing prototypes and pilot plant), than on research activities (i.e. developing, testing and refining scientific laws and models). This is because theoretical laws and models, often developed ‘under laboratory conditions’, or assuming ‘other things being equal’, are unable to predict the operating performance of complex technological artefacts (Pavitt, 1984).

According to Pavitt (1984), these characteristics of technology have a number of major implications for the conceptualisation and measurement of technological activities. First, R&D activities are a necessary complement to the absorption of new technology, as they augment firms' scientific and technological competencies to learn about knowledge, products and processes developed elsewhere. Second, the complexity of technology is its variety because technological knowledge emerges mainly from development and production activities, and therefore pertains to specific products and processes and classes thereof. Last but not least, technologies are classified in terms of their 'technological distance'. Four clusters tend to emerge, based on the four pervasive technological families, each with its distinctive technological competencies and sources of new technology: mechanical, chemical, electrical-electronic and software.

2.2 The Source of Technology

In the 1994 national survey of innovation in industry conducted by Malaysia's Ministry of Science, Technology and the Environment (MoSTE), it is noticed that nearly 89 per cent of innovators in Malaysia are in the manufacturing industries, notably the electronic equipment and components, rubber and plastics products, chemical products, electrical machinery and appliances, basic and fabricated metal products (MoSTE, 1996). As innovation closely relates to an attainment of technology, this finding suggests that manufacturing sector is the main source of technology in Malaysia. Meanwhile, based on MoSTE's (2001) 1997-1999 national survey of innovation report, it is noticed that the incidence of innovation varies from one industry to another in Malaysia. In general, low-technology industries, such as manufacture of wearing apparel, footware, wood and cork products, have very low incidence of innovation – less than 10 per cent of firms in each of these industries carry out innovation activities. Two high-technology industries show high incidence of technological innovation: electrical machinery, apparatus, appliances and supplies, and professional and scientific equipment.

According to the Intellectual Property Division of Malaysia's Ministry of Domestic Trade and Consumer Affairs, over the past 10 years, 90 per cent of the patents for technological products in Malaysia have been granted to the manufacturing firms[2]. This is in line with the [3]Association of the Computer and Multimedia Industry's (PIKOM) survey results of the expenditure on personal computers and Internet by the following industrial sectors in Malaysia: banking and finance, manufacturing, government, telecommunications, distribution, oil and gas, utilities, professional IT and other services, healthcare, education and research, transportation, home and others. According to PIKOM, manufacturing sector, in average, constituted 20 per cent of the total information technology expenditure in Malaysia during the period 1990-2000, the largest among all the sectors.

These survey results are rather similar to the findings of other international studies. Evenson et al (1989) develop a concordance to distribute patents into Industry of Manufacture (IOM) and Sector of Use (SOU). Based on the technology matrix that demonstrates the basic nature of inter-industry invention flows (see Figure 1), it is shown that most non-manufacturing sectors - including agriculture, forestry, fishing, construction, communications, health, finance and trade - depend on manufacturing for much, in some cases most, of their technology. In a follow-up study by Evenson (1993), it is noticed that the patenting indices of manufacturing sector, in average, are higher than those recorded in non-manufacturing sectors (see Table 1).

2.3 The Measurement of Technology

Direct measurement of technological innovation is a desideratum for various economic analyses (Grupp, 1998). Nonetheless, to date, the broader aspects of the knowledge-based economy are not yet measured at the aggregate level, probably because of a lack of any agreed upon framework and general problems with collecting good proxies for knowledge inputs and outputs (Harris, 2000).

[2] It is an unpublished data and obtained upon special request.

[3] PIKOM is the trade association representing the information and communications technology (ICT) industry in Malaysia. Its membership currently stands at 365, comprising companies involved in a whole spectrum of ICT products and services, in turn controlling about 400 companies which command 80 per cent of the total ICT trade in Malaysia.

Measurement debate on international comparisons of innovative inputs and outputs has been increasingly focussed on continual improvement in empirical understanding and resources devoted to the measurement of technological activities. According to Patel et al. (1995), this is because of two practical reasons. First, the growing demand for more reliable information from government, firms and universities, and the rapid development in information technology that enables many new possibilities for analysing scientific results. Second, the continuing emergence of new technological activities creates need for a commonly accepted measurement tool.

Since the early 1990s, MoSTE has been using the Science and Technology (S&T) Indicators to monitor the status of the S&T system in Malaysia and conduct comparative assessment with other countries. The key variables of the S&T Indicators are R&D, patents, bibliometric, technology balance of payment, human resources and so forth. The indicators measure both inputs and outputs. The former includes financial and human resources devoted to R&D activities, which is vital for assessing R&D efforts and determining whether the level of R&D is keeping pace with the expansion of the economy and infrastructure. Meanwhile, the latter refers to investment in S&T that brings possible benefits to the country and it includes applied and granted patents and bibliometric. Besides providing an indication of the quality and capability of the local scientists and engineers, both of them could also measure the innovation level and assess the S&T level of Malaysia, respectively.

Another measurement tool for technology in Malaysia is the Knowledge Imperative Index (KIX) and it is the brainchild of the Malaysian Institute of Microelectronic Systems (MIMOS). According to Ramachandran (1999), the KIX is intended for gauging the level of change towards the formation of an information or knowledge society, arising from the impact of contemporary information and communications technology (ICT). However, conceptually the model is still at the embryonic stage of development and it needs further refinement, in terms of sufficient number of variables for information access and knowledge acculturation domains.

Grupp (1998), on the other hand, has also introduced a method to measure technological innovation. As shown in Figure 2, his Innovation Indicators consist of resource indicators, R&D results indicators and progress indicators. The resource indicators are a generic term embracing every possible means for measuring personnel, monetary and, expenditure on research, development and innovation, such as R&D outlays, R&D personnel statistics, investment statistics and royalties paid. The R&D results indicators, meanwhile, are the results of R&D in direct sense, that is, irrespective of whether or not they are important for the success of generating innovation. The key variables of R&D results indicators are publication, patent statistics and citations. The progress indicators relate to the characteristics and micro- or macroeconomic effects of innovation, such as innovation counts recorded in corporate questionnaires, measurement of high technology markets, calculation of total factor productivity, employment, production growth and macro- foreign trade variables.

3 Methodology

3.1 Technological Knowledge Index and its Component Indices

MoSTE's S&T indicators are intended to track the changes of technology in Malaysia rather than strictly cater for the manufacturing sector. While Grupp's (1998) Innovation Indicators could probably be an appropriate measurement tool for industrial technology, it, however, cannot be imported wholesale to Malaysia. His Innovation Indicators are conceptualised and formulated within the context of a developed nation (Germany) and therefore they need to be customised and adapted. For instance, there are data that may not be available in Malaysia.

Conceptually drawing upon Grupp's (1998) Innovation Indicators, the TKI comprises the following three component indices and twenty four variables that are closely related to the manufacturing sector in Malaysia:

1. *Resource (Inputs of industrial technology development)*

- Number of vocational and technical schools
- Number of students enrolment in vocational and technical schools
- Number of students enrolment in public universities' science and technical courses

- Number of registered engineers
- Capital expenditure in the manufacturing sector (in RM million)
- Government industrial development expenditure (in RM million)
- Loans disbursed by the banking system to the manufacturing sector (in RM million)
- FDI inflows to the manufacturing sector (in RM million)
- Number of FDI projects in the manufacturing sector
- Number of technology and know-how agreements

2. *R&D Result (Throughput of industrial technology development)*

- Number of patents granted to the manufacturing sector

3. *Progress (Outputs of industrial technology development)*

- Gross output value of the manufacturing sector (in RM million)
- Manufacturing production index
- Annual growth rate of the manufacturing sector (in per cent)
- Share of manufacturing sector to the GDP (in per cent)
- Exports of the manufactured goods (in RM million)
- Share of the manufactured exports (in per cent)
- Share of the electrical, electronics and machinery industry's exports (in per cent)
- Labour productivity of the manufacturing sector (in per cent)
- Employment in the manufacturing sector (in per cent)
- Number of new vacancies reported in the manufacturing sector
- Salaries and wages paid in the manufacturing sector (in RM million)
- Industrial index turnover (in RM thousand)
- Number of manufacturing firms

The variables of each index are selected based on their importance, how best they reflect the particular area and conditional upon the availability of time series data. The methodology used for formulating the TKI is adapted from the Malaysian Quality of Life Index of Malaysia's Economic Planning Unit (1999).

The annual data used for the computation of the TKI cover the period 1980-2000, with the exception of data on capital expenditure of the manufacturing sector, number of patents granted to the manufacturing sector and labour productivity in the manufacturing sector. Data for these three variables only available start from 1984, 1988 and 1987, respectively. 1990 is chosen as the base year and its index value equals 100. All the data are extracted either from the Science and Technology Indicators Report (MoSTE, various issues) or the Malaysian Yearbook of Statistics (Department of Statistics, various issues).

To ensure the units in the indices are comparable, it is necessary to standardise the data by using the track record achieved by the historical information of each variable. The standard deviation is used to standardise each of the variables, so that it is amenable to aggregation for the derivation of the composite index, the TKI. The standard deviation enables the determination of the location of the values of a frequency distribution in relation to the mean with greater accuracy. According to Chebysev's theorem, no matter what the shape of the distribution, at least 75 per cent of the values will fall within $\pm$ 2 standard deviations from the mean of the distribution, and at least 89 per cent of the values will lie within $\pm$ 3 standard deviations from the mean. Four steps are involved in the computation of the TKI.

(i) Let the standard score of variable i, subsumed in component j for year t, be denoted by X_{ijt}

$X_{ijt} = (I_{ijt} - I_{ij0})/\sigma_{ij}$

where,

I_{ijt} = Value of variable i in year t
I_{ijo} = Value of variable i in the base year
σ_{ij} = Standard deviation of variable i

(ii) Let S_{ijt} be the sub-index of variable i in component j for year t, where

$S_{ijt} = 100 + 10X_{ijt}$

(iii) The component index for year t is given by the average of the sub-indices of all the variables in component j

$A_{jt} = \sum S_{ijt}/n_j$

i

where,

n_j = Number of variables in component j

(iv) The TKI for year t is obtained by taking the average of all the component indices, which is

$$TKI_t = \sum_j A_{jt}/N$$

where,

N = Number of component indices

The constraints faced in the computation of the TKI are as follows:

(i) *Choice of variables*. The selection of variables to represent each component index is problematic. Due to a lack of time series data, it is difficult to obtain an ideal set of variables that best reflect a component index.

(ii) *Subjective variables*. For a comprehensive assessment, the use of both objective and subjective variables would be more ideal. However, the latter is not used as it requires frequent surveys.

3.1.1 Rationale behind the Selection of Variables

Resource Index

- *Number of vocational and technical schools / Number of students enrolment in vocational and technical schools / Number of students enrolment in public universities' science and technical courses / Number of registered engineers*

As pointed out by Middleton et al. (1993), Tzannatos and Johnes (1997) and, Lall (2001), human capital concept is defined as the stocks of competencies, skills and knowledge in growth and innovation theory. Accessibility to human resources for long-term growth has been emphasised repeatedly and the new growth theory ascribes rising marginal profits to human capital.

Adequate supply of educated, trained and skilled human resources in S&T is a critical factor for the development of industrial technology in Malaysia. These variables are aimed at examining the stocks and flows of highly skilled personnel, particularly engineers and technicians (MoSTE, 1996).

- *Capital expenditure of the manufacturing sector / Government industrial development expenditure / Loans disbursed by the banking system to the manufacturing sector*

  Technological knowledge augmentation and technological change are processes which take place over a period of time, from basic research through to the development and marketing of a new product, and involve the commitment of capital resources at various stages in the process. As capital expenditure refers to additions or acquisitions of assets, the way and amount of financing the capital investment that drive the technological process play a pivotal role in determining the success of technological knowledge accumulation process (Goodacre, 1990; Goodacre and Tonks, 1995; Stoneman, 2001).

- *FDI inflows to the manufacturing sector / Number of FDI projects in the manufacturing sector*

  FDI often involves the transfer of knowledge from one country to another, making it a potentially important vehicle for international technology diffusion. The major benefit expected from foreign investment is the transfer of technology, skills and know-how. Since much of the world's R&D activities have been undertaken within large firms in North America, Europe and Japan, firms from these areas are a potentially rich source of valuable information about innovative, products, manufacturing processes, marketing methods and managerial approaches (Carr et al., 2001; Keller, 2001; Kumar, 1996). As pointed out by Lim and Maisom (2000), FDI has been encouraged in Malaysia mainly because it contributes towards the nation's industrial technology development.

- *Number of technology and know-how agreements*

  According to MoSTE (1996), technology balance of payments measures international trade in intangible technology, including trade in technique, transaction involving intellectual property such as money paid or received for the use of patent, licenses, trademarks, designs and know-how, services with technical contract, such as consultancy and payment for R&D carried out in foreign countries.

Data on national receipts and payments for technology and know-how agreements have been used to assess national strengths and weaknesses in technology. It is the main channels through which embodied and disembodied technology are transferred across international boundaries. Embodied technology is transferred via international trade in producers goods whereas disembodied technology is channelled via the imitation of product innovation through independent R&D and reverse engineering (Patel and Pavitt, 1995).

R&D Result Index

- *Number of patents granted to the manufacturing sector*

  An indicator used by the OECD countries to measure their innovative and inventive level is the number of patent granted to its residents and non-residents (MoSTE, 1996). Patents are treated as the intermediate output of research and development activities with regard to technological knowledge. As a kind of intellectual property rights, the number of patents are used to express the extent of inventive activity that determines the amount of technological knowledge to be generated (Faust and Schedle, 1983; Grupp and Schmoch, 1992; Grupp, 1998).

Progress Index

- *Gross output value of the manufacturing sector / Share of the manufacturing sector to the GDP*

  Sales of goods in gross value refer to the actual amount paid by purchaser (including applicable duties, freight, insurance, etc, paid by the reporting company on the goods in question). Extraordinary revenue, such as realised capital gains or losses and windfall, are excluded. The common approach to deal with the problem of the non-accountability of innovations is to take the revenue of a manufacturing firm as a yardstick for technical progress. In doing so, an economic weighting of the innovation values is introduced, so that, the revenue figures reflect the market value of the manufactured products. However, the disregarding of quality change weighting should be acknowledged as a shortcoming (Meyer-Krahmer, 1984; Grupp, 1998).

- *Manufacturing production index / Annual growth rate of the manufacturing sector*

  Growth induced by technological progress can be deduced for individual branches and markets by determining the net production index. For observers of business cycles, the net industrial production index is among the most important indicators. The net production value can be related to basic prices and hence the true production growth can be shown as the putative correlating progress indicator. After all, net production value is cited as the more suitable index for showing the importance of an industry or a market as it does not hide intermediate inputs (Kaufer, 1989; Grupp, 1998).

- *Exports of the manufactured goods / Share of the manufactured exports / Share of the electrical, electronics and machinery industry's exports*

  Levels and trends in exports of 'high' and 'medium' technology products have been used as indicators of innovative performance. The relative world market share attained by a national economy is the result of the technical quality of the goods being offered. If a national economy has achieved technological leadership in a particular industry, inter-country trade with other national economies is more likely to take place (Patel and Pavitt, 1995). As shown in Table 1, both electrical machinery and electronic equipment industries record relatively high patenting indices.

- *Labour productivity in the manufacturing sector / Employment in the manufacturing sector / Number of new vacancies reported / Salaries and wages paid in the manufacturing sector*

  Consistent with the Verdoon's Law[4], labour productivity of the manufacturing sector in Malaysia is largely dependent on output growth and the impact of output growth on labour productivity can be ascribed to technological progress (Ghosh, 1992). Using Hsiao's (1981) formulation, Ghosh (1992) also notices that the direction of causality runs from output growth to employment growth, and also from output growth to productivity growth. For both perfect and imperfect competition, Spiezia and Vivarelli

[4] Verdoon's Law specifies that, on average, the elasticity of labour productivity with respect to output is 0.45 and the broad range of value lies between 0.41 and 0.57.

(1998) and Loo and Ziesemer (1999) notice that technical change explains a higher percentage of both wage and employment growth.

- *Industrial index turnover*

  This turnover value refers to the volume of the shares of Kuala Lumpur Stock Exchange's main board listed companies traded under the category of Industrial Products. Holding other variables constant, trading volume of a stock market would be higher following an increase in the profitability of its listed companies and this is consistent with the herding behaviour theory (Chan et al, 1999). As the results of both the 1994 and 1997-99 national surveys of innovation in industry show that larger manufacturing companies in terms of profitability are more likely to be innovators (MoSTE, various issues), a new technological development should boost the turnover value. Also, as empirically tested by Greenwood and Jovanovic (1999) and, Hobijn and Jovanovic (2000), a new technology or product developed by a public listed company may likely, at first, temporarily reduce its market capitalisation's value but increase it after the technological innovation shift.

- *Number of manufacturing firms*

  One important evidence about growth can be characterised by the fact that there are many firms in an economy (Romer, 1994). As pointed out by Acs and Audretsch (1987), Symeonidis (1996) and Cowan (2001), the relationship between R&D and number of firms should be positive as the dynamics are such that, more R&D this period imply more knowledge next period. This has two effects. First, it raises the probability that a firm will succeed in its R&D and second, it implies that rival firms are also more likely to succeed.

3.2 Macroeconomic Effects of Industrial Technology

In this study, annual data in natural log form are used to stabilise the series. These data are extracted from the Malaysian Yearbook of Statistics (Department of Statistics, various issues). The eight Malaysian macroeconomic variables to be studied are as follows:

- Consumer Price Index (LCPI)

- Total Exports (LEXPORTS), in RM million
- Gross National Product (LGNP), in RM billion
- Total Imports (LIMPORTS), in RM million
- Total Investment (LIVESTMEN), in RM million
- Stock Market Capitalisation over GDP (LSMCGDP)
- Unemployment Rate (LU)
- Average Wage Changes (LWAGES), in per cent

Other related macroeconomic variables to be used in the study are as follows:

- Domestic Interest Rate (R)
- Gross National Savings (LGNS), in RM million
- Real Effective Exchange Rate (LREER)
- Total Consumption Expenditure (LCSUMTION), in RM million
- Labour Force (LLABOUR), in thousands

The following are the linear functions of the equation models and the expected signs of their parameters:

1. $LCPI = f_1 (\underset{-}{LTKI}, \underset{+}{LCSUMTION}, \underset{-}{R})$

2. $LEXPORTS = f_2 (\underset{+}{LTKI}, \underset{-}{LREER}, \underset{+}{LGDP})$

3. $LGNP = f_3 (\underset{+}{LTKI}, \underset{+}{LGNS}, \underset{-}{R})$

4. $LIMPORTS = f_4 (\underset{+}{LTKI}, \underset{+}{LREER}, \underset{+}{LGDP})$

5. $LIVESTMEN = f_5 (\underset{+}{LTKI}, \underset{-}{R})$

6. $LSMCGDP = f_6 (\underset{+}{LTKI}, \underset{-}{R})$

7. $LU = f_7 (\underset{-}{LTKI}, \underset{-}{LGDP})$

8. $LWAGES = f_8 (\underset{+}{LTKI}, \underset{-}{LLABOUR}, \underset{+}{LGNP})$

Phillips-Perron unit root test is employed to establish the time series properties of data. Such unit root test is required to examine the order of integration of each variable. Results of the test show that except for R, which is stationary or I(0), the other variables contain unit root problem and are non-stationary, but all with the same order of integration, I(1). See Table 2.

The commonly applied Johansen cointegration test will be run to test for the existence of a long run relationship between the variables included in each equation model. However, since Johansen cointegration test is more suitable for large samples, the small sample method proposed by Pesaran et al.'s (2001) will also be used to test the existence of a level relationship between a dependent variable and a set of regressors.

Pesaran et al.'s (2001) method allows for inferences that are robust, irrespective of whether the variables are I(0) or I(1). Moreover, this approach does not rely on assumptions about the exogeneity or otherwise of the variables. Based on this approach, the following unrestricted version of the Autoregressive Distributed Lag Model (ARDL) is used to carry out the cointegration test:

1. $\Delta LCPI_t = \mu + \alpha LCPI_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$

where $Z_t = (LCPI_t, LTKI_t, LCSUMTION_t, R_t)' = (LCPI_t, X_t')'$; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

2. $\Delta LEXPORTS_t = \mu + \alpha LEXPORTS_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$

where $Z_t = (LEXPORTS_t, LTKI_t, LREER_t, LGDP_t)' = (LEXPORTS_t, X_t')'$; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

3. $\Delta LGNP_t = \mu + \alpha LGNP_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$

where Z_t = ($LGNP_t$, $LTKI_t$, $LGNS_t$, R_t)′ = ($LGNP_t$, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

$$4.\ \Delta LIMPORTS_t = \mu + \alpha LIMPORTS_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$$

where Z_t = ($LIMPORTS_t$, $LTKI_t$, $LREER_t$, $LGDP_t$)′ = ($LIMPORTS_t$, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

$$5.\ \Delta LIVESTMEN_t = \mu + \alpha LIVESTMEN_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$$

where Z_t = ($LIVESTMEN_t$, $LTKI_t$, R_t)′ = ($LIVESTMEN_t$, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

$$6.\ \Delta LSMCGDP_t = \mu + \alpha LSMCGDP_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$$

where Z_t = ($LSMCGDP_t$, $LTKI_t$, R_t)′ = ($LSMCGDP_t$, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

$$7.\ \Delta LU_t = \mu + \alpha LU_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$$

where Z_t = (LU_t, $LTKI_t$, $LGDP_t$)′ = (LU_t, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

$$8.\ \Delta LWAGES_t = \mu + \alpha LWAGES_{t-1} + \beta' X_{t-1} + \sum_{i=1}^{p-1} \psi'_i \Delta Z_{t-i} + \delta' \Delta X_t + u_t$$

where Z_t = ($LWAGES_t$, $LTKI_t$, $LLABOUR_t$, $LGNP_t$)′ = ($LWAGES_t$, X_t′)′; μ, u_t and p are the constant, random error terms and lag order of the underlying VAR respectively.

Due to limited time series data, sufficiently small p of 2 is chosen, so that these equation models are not unduly over-parameterised. Ordinary least squares method is used to estimate the equations. Based on the approach of Pesaran et al. (2001), these dynamic equation models can be estimated by examining the F-statistics from a hypothesis test that the level coefficients of the variables are zero. In all cases, the F-statistics are computed for testing. The asymptotic distribution of the F-statistics is non-standard. Pesaran et al. (2001) have tabulated the appropriate critical bounds of the F-statistics for different numbers of regressors, irrespective of whether the ARDL model contains an intercept and/or trend. The same approach has also been used by Wickramanayake (2000), Bakhshi and Yates (1998) and Senhadji (1998) for small samples.

4 Results

4.1 Technological Knowledge Index and its Component Indices

As shown in Figure 3, except for the R&D Result Index (RDRI), the Resource Index (RI), Progress Index (PI) and Technological Knowledge Index (TKI) had exhibited an upward trend during the period 1980-2000.

The RI was edging up steadily from 1980 to 1990, despite the 1985 economic recession had temporarily set back four of its variables, namely the capital expenditure in the manufacturing sector, the number of FDI projects in the manufacturing sector, the number of technology and know-how agreements and, the government industrial development expenditure. To a large extent, the sharp increase in the FDI inflows after the 1986 Plaza Accord had offset the decline in these four variables. However, during the period 1990-97, while Malaysia's economy was at a brisk pace, the RI seemed to have lost its growth momentum as it was trudging along horizontally. This is within reason as four of its variables, namely the FDI inflows to the manufacturing sector, the number of FDI projects in the manufacturing sector, the number of technology and know-how agreements and, the government industrial development expenditure, had headed south. Thanks to the substantial increase in the number of students enrolment in public universities' science and technical courses, the number of registered engineers and the number of technology and know-how agreements, the RI was able to stage a mild recovery immediately after the 1997 Southeast Asian currency crisis that sent three of its variables, namely the capital expenditure in the manufacturing sector, the FDI inflows to the manufacturing sector and the number of FDI projects in the manufacturing sector, to a tail-spin.

Although the RDRI outperformed the other indices during the period 1988-1996, it tumbled from 1997 onwards. The sharp drop in the RDRI implies that the number of patents granted to the manufacturing firms in Malaysia had declined significantly. Since patent is a throughput of R&D, this suggests that the manufacturing firms, which are mostly MNCs, had substantially reduced their R&D activities. If this downward trend is not immediately reversed, most likely the technological innovation level of Malaysia would sink over time.

It is delighted to note that the PI grew sturdily throughout the period 1980-2000, outperformed all the other three indices. However, compared to the RI, the PI tended to be more volatile and vulnerable to unfavourable economic conditions. For instance, it fell when the economic malaise loomed in both 1985 and 1998.

Similar to the RI and PI, the TKI grew quite firmly during the period 1980-1996. However, largely due to the sharp fall in the RDRI, the TKI slid slightly from 1997 onwards, despite the sound performance of both the RI and PI. Thankfully, the temporary setback beleaguered the TKI during the period 1996-98 was seen to have stabilised from 1999 onwards.

In conclusion, the commendable performance of the TKI throughout the period 1980-2000 suggests that the technology level of Malaysia, particularly in the manufacturing sector, had been improving gradually over the years. Nonetheless, it has to be cautiously noted that, the RDRI continued sliding and both the RI and TKI were ebbing away slowly towards the end 1990s.

4.2 Macroeconomic Effects of Industrial Technology

The cointegration results obtained by using Johansen cointegration test and Bounds F-test of Pesaran et al. (2001) for the eight equation models with the dependent variables:

$LCPI_t$, $LEXPORTS_t$, $LGNP_t$, $LIMPORTS_t$, $LIVESTMEN_t$, $LSMCGDP_t$, LU_t and $LWAGES_t$, are tabulated in Table 3.

Based on Johansen cointegration test, the four variables: $LEXPORTS_t$, $LTKI_t$, $LREER_{t-1}$ and $LGDP_t$ in equation model 2, the three variables: $LGNP_t$, $LTKI_t$ and $LGNS_t$ in equation model 3, the four variables: $LIMPORTS_t$, $LTKI_t$, $LREER_{t-1}$ and $LGDP_t$ in equation model 4 and the four variables: $LWAGES_t$, $LTKI_{t-1,}$ $LLABOUR_t$ and $LGNP_t$ in equation model 8 are cointegrated. However, based on Pesaran et al.'s (2001) approach, only the four variables in equation model 8 are cointegrated as shown by the significant Bounds F-statistic. The significant estimated residual ($Residest_{t-1}$) generated by OLS regression may further substantiate it.

The Johansen's approach based estimated error correction terms (ECT_{t-1}) show that the speed of adjustment back towards long run equilibrium after a shock is reasonable and acceptable. The coefficient of the ECT_{t-1} in estimated equation model 2 suggests that 49 per cent of the disequilibrium would be eliminated in the following year. The coefficients of the ECT_{t-1} in estimated equation models 3(i) and 4(i) imply that 73 per cent and 37 per cent of the disequilibrium would be removed after one year, respectively. The coefficient of the ECT_{t-1} in estimated equation model 8(i) is more than 1 and this indicates that the disequilibrium would be removed within a year.

All the t-statistics of the estimated coefficients of TKI_t in the eight equation models are statistically significant (see Table 4). Meanwhile, the t-statistics of the estimated coefficients of the other exogenous variables are also statistically significant except for $LCSUMTION_t$ in equation model 1, $LREER_{t-1}$ in equation model 2(ii), R_{t-1} in equation model 3(i), $LREER_{t-1}$ in equation models 4(i) and 4(ii), R_t in equation model 6, $LGDP_t$ in equation model 7. F-statistics, standard errors, Durbin-Watson statistics, Akaike info criterion and Schwarz criterion of the eight regression models are satisfactory. The null hypothesis that the residuals of the estimated equation are not first-order serially correlated against the two-sided alternative hypothesis has also been tested. As shown by the results of serial correlation LM test, there is no evidence of first-order residual autocorrelation except for equation model 6. Based on the results of Ramsey's RESET test, except for estimated equation models 3(i) and 4(ii), the others are reasonably specified. Also, the results of White's Heteroscedasticity test suggest that the errors of most estimated equation models are homoscedastic. On the whole, the estimated equation models are consistent with the hypothesis given in the methodology and the overall satisfactory diagnostics are an indication of the robustness of the eight estimated equation models.

4.2.1 Effect on $LCPI_t$

The results show that every increase of 1 per cent in $LTKI_t$ would have a tendency to decrease $LCPI_t$ by 20.81 per cent. The effect caused by $LTKI_t$ is bigger than the other two exogenous variables, $LCSUMTION_t$ and R_{t-1}. However, the coefficient of $LCSUMTION_t$ is not significant. Every increase of 1 per cent in $LCSUMTION_t$ would have a tendency to increase $LCPI_t$ by 0.83 per cent while every increase of 1 per cent in R_{t-1} would have a tendency to decrease $LCPI_t$ by 0.30 per cent, respectively.

This is in line with the findings of Mincer (1996) and, Mincer and Danninger (2001), who empirically show that cost reduction and product innovation are the contributions of technology to the capacity of the economy as these ought to exert downward pressure on prices.

4.2.2 Effect on $LEXPORTS_t$

The results show that every increase of 1 per cent in $LTKI_t$ would have a tendency to increase $LEXPORTS_t$ by 0.86 per cent. $LTKI_t$ has a bigger effect on $LEXPORTS_t$ than the other two exogenous variables, $LREER_{t-1}$ and $LGDP_t$. Every increase of 1 per cent in $LREER_{t-1}$ would have a tendency to decrease $LEXPORTS_t$ by 0.05 per cent while every 1 per cent increase in $LGDP_t$ would have a tendency to increase $LEXPORTS_t$ by 0.58 per cent.

This is in line with the findings of Kumar and Siddharthan (1993) and Barba and Mattozzi (1998), who find technology to be important in explaining inter-firm variation in the export behaviour of developing countries. They have emphasised the contribution of technology and skills to countries' relative export competitiveness and observed that industries associated with a relatively high 'research effort' tend to export a relatively high proportion of their output.

4.2.3 Effect on $LGNP_t$

The results show that every increase of 1 per cent in $LTKI_t$ would have a tendency to increase $LGNP_t$ by 0.74 per cent. The effect of $LTKI_t$ on $LGNP_t$ is bigger compared to the other two exogenous variables, $LGNS_t$ and R_{t-1}. Every increase of 1 per cent in $LGNS_t$ would have a tendency to increase $LGNP_t$ by 0.10 per cent while every increase of 1 per cent in R_{t-1} would have a tendency to decrease $LGNP_t$ by 0.005 per cent.

Trefler (1995), Harrigan (1995) and Moreno (1997) emphasise on the role of technology in influencing international trade and demonstrate the importance of technological differences in it. As documented by Teubal (2002), business sector, which has a comparative advantage in generating technological development, is the backbone of national innovation systems' transformation process and it generates a large increasing share of GNP and growth. In Malaysia, it is the manufacturing sector that has increasingly expanded the intra- and inter-regional trade of the nation since the early 1980s, which has in turn, contributed significantly towards the nation's GNP growth over the years (Wee, 2002).

4.2.4 Effect on $LIMPORTS_t$

The results show that every increase of 1 per cent in $LTKI_t$ would have a tendency to increase $LIMPORTS_t$ by 1.20 per cent. However, every 1 per cent increase in $LREER_t$ would have a tendency to increase $LIMPORTS_t$ by only 0.01 per cent. Meanwhile, every increase of 1 per cent in $LGDP_t$ would have a tendency to cause $LIMPORTS_t$ increases by 1.94 per cent.

As pointed out by Kumar and Siddharthan (1993) and Lall (1995), manufacturing firms in developing countries still widely resort to importing to fulfil their technology requirements. They are dependent on their local technological capability for imitation, adaptation or absorption to allow for diffusion of technological innovations from the North as it is unlikely for them to achieve competitive advantage on the basis of their own technological activities in high technology industries (Krugman, 1979).

4.2.5 Effect on $LIVESTMEN_t$

The results show that every increase of 1 per cent in $LTKI_{t-1}$ would have a tendency to increase $LIVESTMEN_t$ by 6.96 per cent. Meanwhile, every increase of 1 per cent in R_{t-1} would have a tendency to decrease $LIVESTMEN_t$ by 0.02 per cent.

This is in line with the findings of Stoneman (1983) and Parente (1995), who empirically show that a firm must make an investment in order to advance its technology and the size of the investment depends on the size of the technology adoption barriers in the firm's country.

4.2.6 Effect on $LSMCGDP_t$

The results show that every increase of 1 per cent in $LTKI_t$ would have a tendency to increase $LSMCGDP_t$ by 9.52 per cent. Nonetheless, the coefficient of another exogenous variable, R_t, is not significant and every 1 per cent increase in R_t would have a tendency to increase $LSMCGDP_t$ by only 0.03 per cent.

This is in line with the findings of Greenwood and Jovanovic (1999) and, Hobijn and Jovanovic (2000) who argue that IT revolution is behind this. A major technological innovation causes the stock market to be temporarily undervalued until the claims to future dividends enter the stock market via initial public offerings (IPO). In other words, the aggregate capitalisation falls below the present value of dividends because a chunk of the dividend-yielding capital stock is temporarily missing from the stock market. Capital is likely to 'disappear' during epochs of major technological change because this is when new capital forms in small, private companies. Only when a private company promises to be successful in its IPO, only then does its capital stock become a part of stock market capitalisation.

4.2.7 Effect on LU_t

The results show that every increase of 1 per cent in $LTKI_{t-1}$ would have a tendency to decrease LU_t by 2.70 per cent. However, the coefficient of another exogenous variable, $LGDP_t$, is not significant and every 1 per cent increase of it would have a tendency to decrease LU_t by only 0.81 per cent.

This is in line with the findings of Stoneman (1983), Cyert and Mowery (1988) and, Mincer and Danninger (2001) who conclude that the pace of technology has unclear effects on aggregate unemployment in the short run, but appears to reduce it in the longer run. A short run increase in the pace of technology may increase the demand for skilled labour, thereby reducing its low levels of unemployment while unemployment of the unskilled may but need not increase. Therefore, the ratio is likely to widen, but aggregate unemployment does not necessarily change significantly. In the longer run, total unemployment would decline when training is extended to less skilled groups as well.

4.2.8 Effect on $LWAGES_t$

The results show that every increase of 1 per cent in $LTKI_{t-1}$ would have a tendency to increase $LWAGES_t$ by 8.41 per cent. Meanwhile, $LWAGES_t$ would have a tendency to decrease by 13.19 per cent and increase by 5.24 per cent for every increase of 1 per cent in $LLABOUR_t$ and $LGNP_t$, respectively.

This is in line with the findings of Bartel and Sicherman (1999), Flor (2001) and Morrison and Siegel (2001) who show evidence that high technology sectors of the economy utilise human capital to a greater extent than other sectors and that relative wages are higher for more educated workers in such sectors. Workers' wage profiles tend to be steeper in these sectors as a result of greater profitability of training and learning in them.

5 Concluding Remarks

An index is required to objectively measure the changes of industrial technology as manufacturing sector is the main source of technology in an economy. In recent years, although the OECD countries have come up with indices for measuring it, Malaysia has yet to invent its own one within the context of technology in the manufacturing sector.

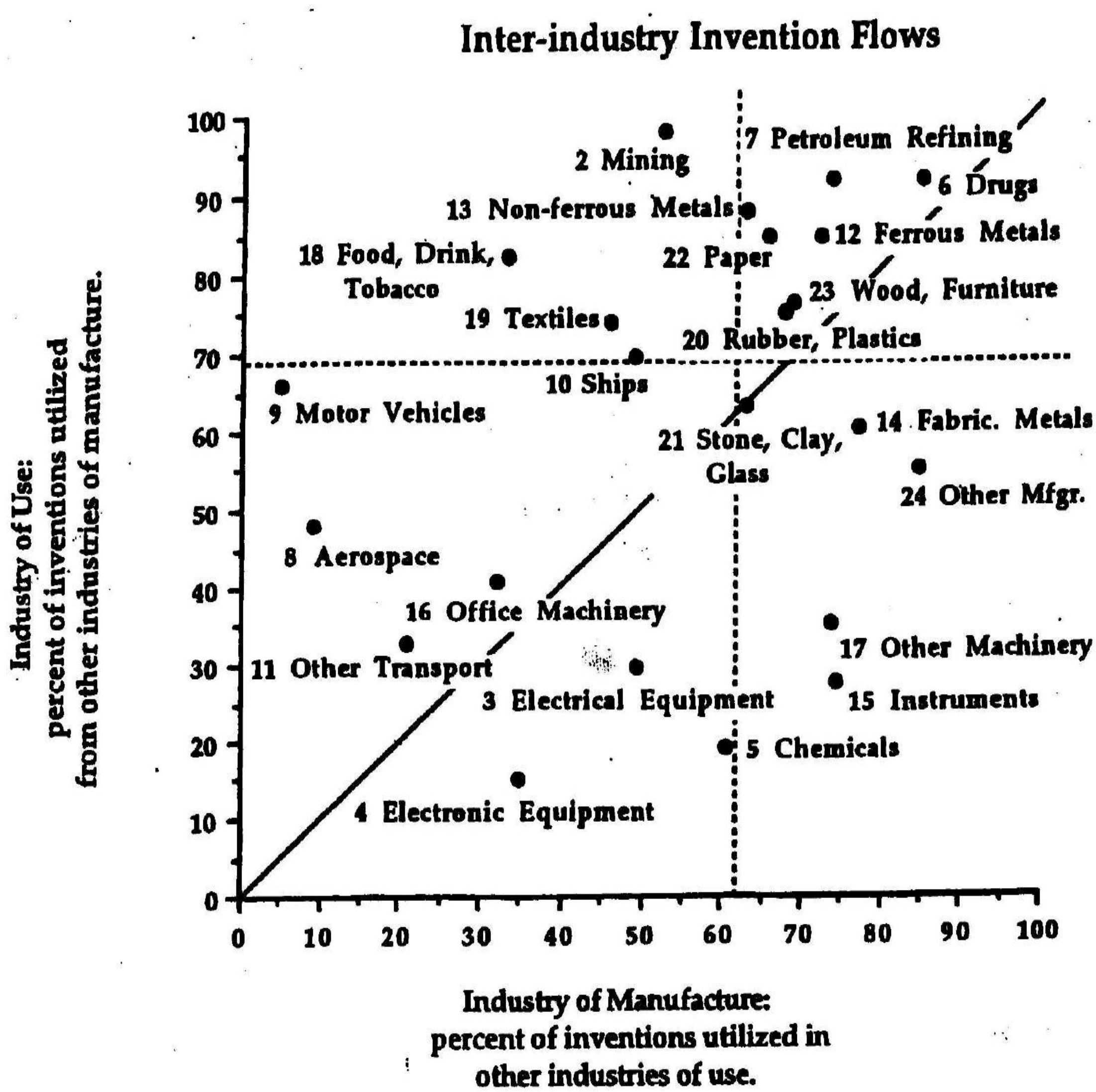
The formulation of the TKI, an index modelled on Grupp's (1998) innovation indicators, is intended for measuring the changes of technology in the manufacturing sector of Malaysia during the period 1980-2000. It comprises three component indices, namely the RI, RDRI and PI, and twenty-four variables, which are closely related to the manufacturing sector.

The results show that, except for the RDRI, the RI, PI and TKI had exhibited an upward trend during the period 1980-2000. This suggests that the technology level of Malaysia, in particular in the manufacturing sector, has been improving gradually over the years. However, it has to be cautiously noted that, the RDRI continued sliding and both the RI and TKI were slowly ebbing away towards the end 1990s.

Making use of the TKI, a study has been conducted on the effects of industrial technology on the following macroeconomic variables: consumer price index, total exports, gross national product, total imports, total investment, stock market capitalisation over GDP, unemployment rate and annual wage changes. The results show that industrial technology helps improving all these eight macroeconomic variables. Based on Johansen cointegration test, the four variables: $LEXPORTS_t$, $LTKI_t$, $LREER_{t-1}$ and $LGDP_t$, the three variables: $LGNP_t$, $LTKI_t$ and $LGNS_t$,, the four variables: $LIMPORTS_t$, $LTKI_t$, $LREER_{t-1}$ and $LGDP_t$ and the four variables: $LWAGES_t$, $LTKI_{t-1,}$ $LLABOUR_t$ and $LGNP_t$ are cointegrated. However, based on Pesaran et al.'s (2001) approach, only the four variables: $LWAGES_t$, $LTKI_{t-1}$, $LLABOUR_t$ and $LGNP_t$ are cointegrated.

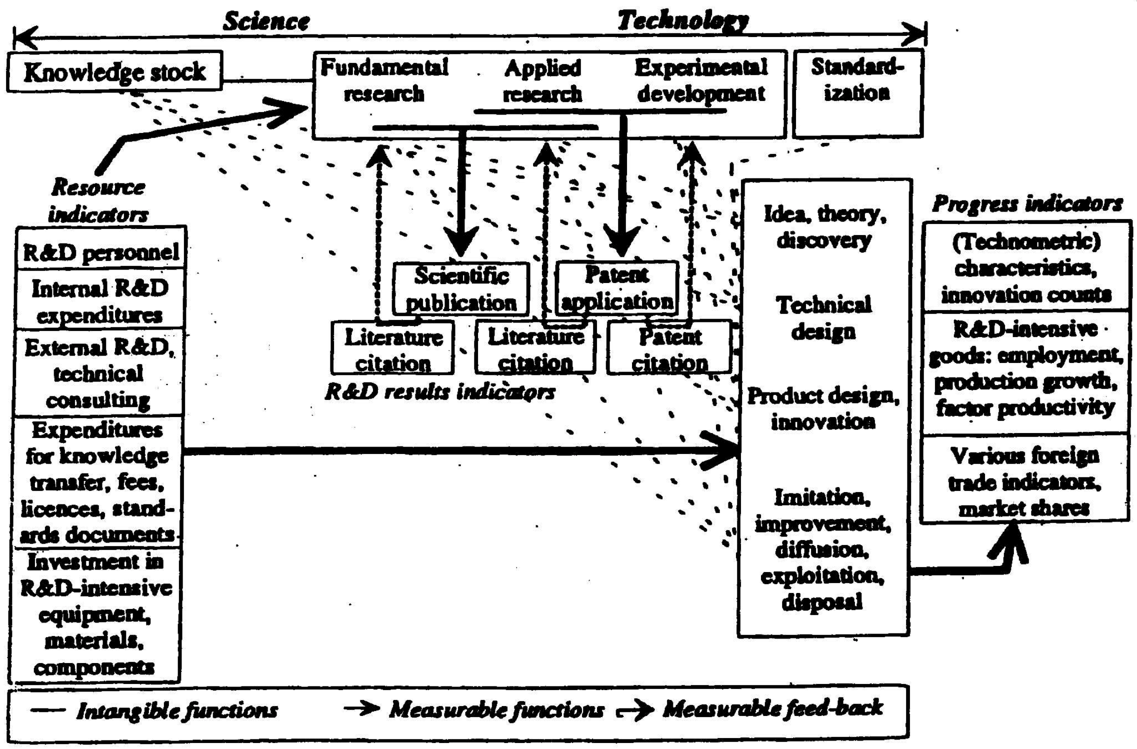
As more time series data are available over time, a further research could be done to improve the set of variables used for each component index. Also, research on the effects of industrial technology at sector and firm levels is worth exploring in Malaysia.

Figure 1



Source: Evenson et al. (1989)

Figure 2

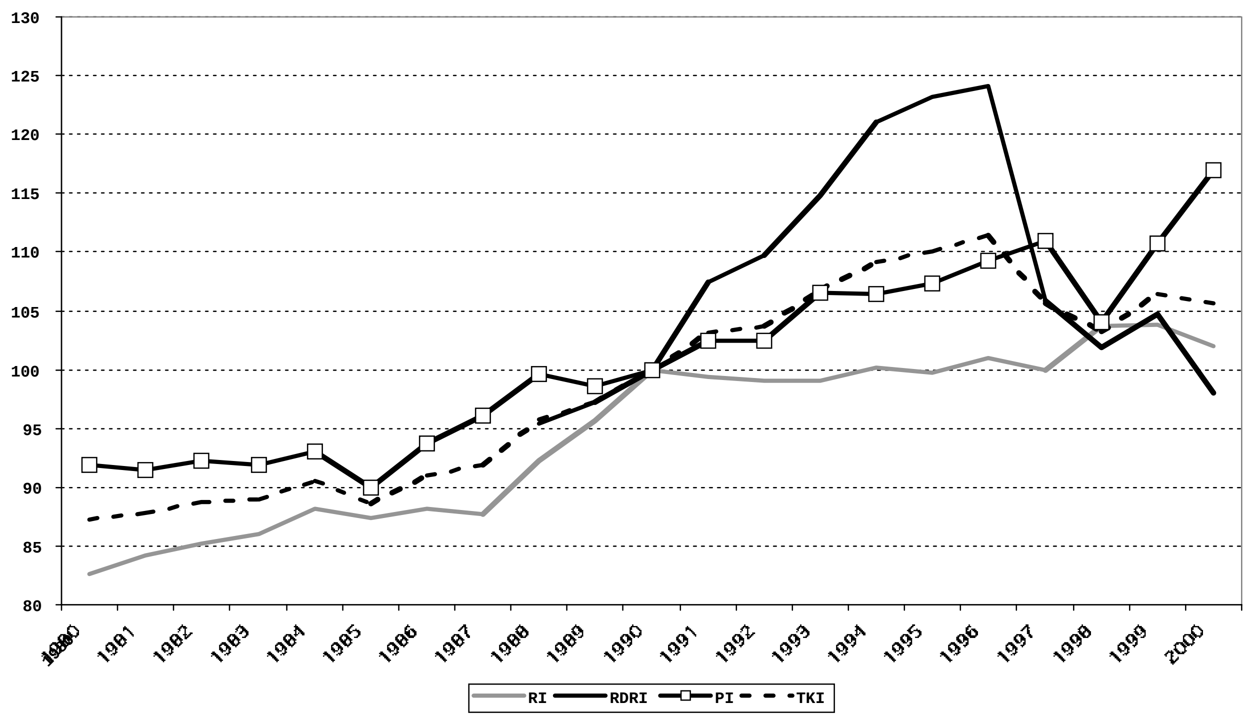


Survey of important innovation indicators and their typology

Source: Grupp (1998)

Figure 3

The TKI and its Component Indices



Descriptive Statistics:

	RI	RDRI	PI	TKI
Mean	94.53	107.95	100.75	98.72
Median	99.00	105.88	100.00	100.00
Maximum	103.79	124.09	116.98	111.44
Minimum	82.60	95.40	89.97	87.24
Std. Dev.	7.21	9.99	7.85	8.41
Skewness	-0.29	0.45	0.28	-0.04
Kurtosis	1.41	1.72	1.99	1.46
Jarque-Bera	2.53	1.32	1.17	2.08
Probability	0.28	0.52	0.56	0.35
Observations	21	13	21	21

Notes:

RI: Resources Index
RDRI: R&D Result Index
PI: Progress Index
TKI: Technological Knowledge Index

Table 1

Sectoral Inter-country Patenting Indices (Eight OECD Countries 1969-1987)

Sector	Inter-Country Patenting Indices	
	Industry of Manufacture	Sector of Use
Finance – Business	-	1.687
Wood & Furniture	1.620	1.705
Construction	-	1.735
Transportation Services	-	1.767
Ships	1.664	1.779
Other Manufacturing	1.719	1.814
Other Services	-	1.866
Fabricated Metals	1.806	1.887
Mining	1.842	1.903
Aerospace	1.876	1.929
Other Transport	1.642	1.961
Agriculture	-	1.966
Communication – Utilities	-	2.002
Health Services	-	2.031
Motor Vehicles	2.009	2.044
Other Machinery	2.060	2.084
Food, Drink & Tobacco	2.271	2.106
Electrical Machinery	2.122	2.185
Electronic Equipment	2.199	2.201
Ferrous Metals	2.195	2.217
Instruments	2.015	2.239
Stone, Clay & Glass	2.093	2.260
Petroleum Refineries	2.179	2.264
Rubber and Plastics	1.952	2.381
Paper and Printing	1.900	2.470
Non-Ferrous Metals	2.548	2.483
Textiles and Clothing	2.019	2.488
Chemicals	2.788	2.788
Drugs	2.696	3.039
Office Machinery	2.071	4.345

Source: Evenson (1993)

Table 2

Phillips-Perron Unit Root Test Results

Variables	Level			First Difference			OI
	Lag 1	**Lag 2**	**Lag 3**	**Lag 1**	**Lag 2**	**Lag 3**	
$LCPI_t$	-2.25	-2.63	-2.33	-4.30^{***}	-4.32^{***}	-4.73^{***}	I(1)
$LCSUMTION_t$	-0.24	-0.19	-0.08	-3.05^{**}	-2.88^{*}	-2.66^{*}	I(1)
$LEXPORTS_t$	0.46	0.58	0.76	-3.75^{**}	-3.78^{**}	-4.27^{***}	I(1)
$LGDP_t$	0.07	0.20	0.27	-4.07^{***}	-4.07^{***}	-4.12^{***}	I(1)
$LGNP_t$	-0.27	-0.27	-0.27	-4.44^{***}	-6.23^{***}	-21.23^{***}	I(1)
$LGNS_t$	0.24	2.03	1.17	-4.49^{***}	-20.57^{***}	-5.45^{***}	I(1)
$LIMPORTS_t$	-0.25	-0.24	-0.11	-3.40^{**}	-3.06^{**}	-2.80^{*}	I(1)
$LIVESTMEN_t$	-1.16	-1.15	-1.11	-2.99^{*}	-2.83^{*}	-2.69^{*}	I(1)
$LLABOUR_t$	0.03	0.14	0.08	-3.54^{**}	-3.50^{**}	-3.45^{**}	I(1)
R_t	-3.88^{**}	-3.84^{**}	-3.70^{**}	-	-	-	I(0)
$LREER_t$	-0.86	-0.74	-0.64	-3.47^{**}	-3.35^{**}	-3.37^{**}	I(1)
$LSMCGDP_t$	-1.85	-1.73	-2.10	-5.08^{***}	-5.69^{***}	-5.05^{***}	I(1)
$LTKI_t$	-1.09	-1.11	-1.12	-3.64^{**}	-3.75^{**}	-3.81^{**}	I(1)
LU_t	-0.86	-1.03	-1.10	-3.02^{*}	-3.16^{**}	-3.21^{**}	I(1)
$LWAGES_t$	-2.69^{*}	-2.87^{*}	-2.49	-4.95^{***}	-4.94^{***}	-10.07^{***}	I(1)

*** Significant at 1 per cent level; **Significant at 5 per cent level; * Significant at 10 per cent level.

Notes:

- OI = Order of integration
- The reported numbers in the column are the Phillips and Perron (1988) test statistics for testing the null hypothesis of a unit root
- All the above variables become stationary after differencing

Table 3
Cointegration Test Results

Variables	Johansen Cointegration Test Likelihood Ratio H_o:r=0	H_o:r=1	H_o:r=2	H_o:r=3	Pesaran et al. (2001) Bounds F-Statistics (ARDL)
$LCPI_t$ $LTKI_{t-1}$ $LCSUMTION_t$	25.18	7.73	0.00	-	2.17
$LEXPORTS_t$ $LTKI_t$ $LREER_{t-1}$ $LGDP_t$	84.71^{**}	25.16	11.08	1.10	3.92
$LGNP_t$ $LTKI_t$ $LGNS_t$	38.86^{**}	9.33	2.44	-	1.49
$LIMPORTS_t$ $LTKI_t$ $LREER_{t-1}$ $LGDP_t$	64.31^{**}	30.99	16.79	7.08	0.53
$LIVESTMEN_t$ $LTKI_{t-1}$	12.07	4.11	-	-	0.94
$LSMCGDP_t$ $LTKI_t$	8.91	1.63	-	-	1.43
LU_t $LTKI_{t-1}$ $LGDP_t$	21.11	6.45	0.26	-	1.97
$LWAGES_t$ $LTKI_{t-1}$ $LLABOUR_t$ $LGNP_t$	54.30^{*}	21.74	8.14	-	9.41♠

Notes:

- r = number of cointegrating relationship.
- $^{*}(^{**})$ denote rejection of the hypothesis at 5 per cent (1 per cent) significance level
- ♠ passes the cointegration test at 1 per cent (5 per cent) level of statistical significance with the critical value bounds of 5.15, 6.36 (3.79, 4.85) for two regressors with constant and no trend from Pesaran et al. (2001)

Table 4

Equation No.	**1**	**2(i)**	**2(ii)**	**3(i) Dependent**
Variable	$\Delta LCPI_t$	$\Delta LEXPORTS_t$	$\Delta LEXPORTS_t$	$\Delta LGNP_t$
Estimates :				
Constant	2.24	0.05	0.07	0.05
	(2.94)***	(3.47)***	(5.71)***	(2.14)**
$\Delta LTKI_t$	-	0.96	0.86	0.67
		(2.80)***	(2.30)**	(2.69)**
$\Delta LTKI_{t-1}$	-20.81	-	-	-
	(-1.87)**			
$\Delta LREER_{t-1}$	-	-0.26	-0.05	-
		(-1.86)*	(-0.44)	
$\Delta LCSUMTION_t$	0.83	-	-	-
	(0.17)			
$\Delta LGDP_t$	-	0.79	0.58	-
		(4.42)***	(3.59)***	
$\Delta LGNS_t$	-	-	-	0.23
				(3.87)***
R_{t-1}	-0.30	-	-	-0.003
	(-3.36)***			(-0.99)
ECT_{t-1}	-	-0.49	-	-0.73
		(-2.06)**		(-3.55)***
Diagnostics:				
$\bar{R}^2$	0.41	0.67	0.60	0.63
F-Statistic	5.20	10.16	9.96	9.19
S.E. of Regression	0.68	0.03	0.03	0.02
Durbin-Watson Stat	1.87	2.08	2.36	1.55
Akaike info criterion	2.26	-4.03	-3.87	-4.41
Schwarz criterion	2.46	-3.78	-3.67	-4.16
RRT (F-statistic)	0.05	0.28	0.05	7.03**
S.C. LM $Test_1$ (nR^2)	0.02	0.71	0.94	0.99
S.C. LM $Test_2$ (nR^2)	0.04	3.72	7.27	2.90
S.C. LM $Test_3$ (nR^2)	0.49	3.80	7.35	5.12
WHT (nR^2)	12.23*	14.86*	4.66	16.82*

Equation No.	**3(ii)**	**4(i)**	**4(ii)**	**5**
Dependent Variable	$\Delta LGNP_t$	$\Delta LIMPORTS_t$	$\Delta LIMPORTS_t$	$\Delta LIVESTMEN_t$
Estimates :				
Constant	0.08	-0.02	-0.03	0.12
	(2.79)***	(-1.13)	(-1.39)*	(1.55)*
$\Delta LTKI_t$	0.74	1.21	1.20	-
	(2.24)**	(1.82)*	(1.66)*	
$\Delta LTKI_{t-1}$	-	-	-	6.96
				(6.52)***
$\Delta LREER_{t-1}$	-	0.21	0.01	-
		(0.98)	(0.05)	
$\Delta LGDP_t$	-	1.88	1.94	-
		(6.57)***	(6.31)***	
$\Delta LGNS_t$	0.10	-	-	-
	(1.66)*			
R_{t-1}	-0.005	-	-	-0.02
	(-1.42)*			(-1.67)*
ECT_{t-1}	-	-0.37	-	-
		(-1.88)*		
Diagnostics :				
$\bar{R}^2$	0.37	0.79	0.75	0.77
F-Statistics	4.66	17.76	19.26	31.16
S.E. of Regression	0.03	0.06	0.06	0.10
Durbin-Watson Stat	1.93	1.69	1.95	2.38
Akaike info criterion	-3.90	-2.68	-2.56	-1.72
Schwarz criterion	-3.70	-2.43	-2.36	-1.57
RRT_1 (F-statistic)	1.37	3.91	5.05*	4.00
S.C. LM $Test_1$ (nR^2)	0.06	0.61	0.00	1.27
S.C. LM $Test_2$ (nR^2)	0.16	2.14	0.99	3.21
S.C. LM $Test_3$ (nR^2)	0.40	3.89	1.35	5.54
WHT (nR^2)	9.20	16.34*	8.37	10.63*

Equation No.	6	7	8(i)	8(ii)
Dependent Variable	$\Delta LSMCGDP_t$	ΔLU_t	$\Delta LWAGES_t$	$\Delta LWAGES_t$
Estimates :				
Constant	-0.25 (-1.06)	0.05 (1.22)	0.10 (1.14)	0.09 (0.99)
$\Delta LTKI_t$	9.52 (2.99)**	-	-	-
$\Delta LTKI_{t-1}$	-	-2.70 (-1.68)*	4.98 (1.93)*	6.06 (2.29)**
$\Delta LLABOUR_t$	-	-	-12.83 (-4.07)***	-12.49 (-3.82)***
$\Delta LGNP_t$	-	-	3.86 (2.00)**	3.61 (1.79)*
$\Delta LGDP_t$	-	-0.81 (-1.11)	-	-
R_t	0.03 (0.85)	-	-	-
ECT_{t-1}	-	-	-1.44 (-7.04)***	-
$Residest_{t-1}$	-	-	-	-1.46 (-6.71)***
Diagnostics :				
$\bar{R}^2$	0.27	0.37	0.80	0.79
F-Statistic	4.48	6.37	19.56	17.90
S.E. of Regression	0.30	0.11	0.18	0.19
Durbin-Watson Stat	2.76	1.85	1.67	1.58
Akaike Info Criterion	0.57	-1.40	-0.36	-0.28
Schwarz Criterion	0.72	-1.25	-0.11	-0.04
RRT (F-statistic)	2.65	2.57	0.18	0.20
S.C LM $Test_1$ (nR^2)	3.11	0.01	0.42	0.77
S.C LM $Test_2$ (nR^2)	6.31*	0.27	1.25	2.76
S.C LM $Test_3$ (nR^2)	8.13**	1.60	5.40	7.46
WHT (nR^2)	5.18	8.24	11.45	12.88

Notes:

(i) is the model fitted based on results of Johansen cointegration test.

(ii) is the model fitted based on results of Pesaran et al.'s (2001) approach.

*** Significant at 1 per cent level
** Significant at 5 per cent level
* Significant at 10 per cent level
*** Significant F-statistic at 1 per cent level
** Significant F-statistic at 5 per cent level

** Significant χ^2 value at 5 per cent level

S.C. LM $Test_i$ (Breusch-Godfrey Serial Correlation LM Test for Lag *i*)

RRT (Ramsey RESET Test with 1 fitted term)

WHT (White Heteroskedasticity, with cross terms)

Table 5

Cointegrating Equations

Johansen cointegration test

2(i). $LEXPORTS_t = -12.16 + 0.78LTKI_t - 0.14LREER_{t-1} + 1.69LGDP_t$
$(10.09)^{***}$ $(7.70)^{***}$ $(94.93)^{***}$

3(i). $LGNP_t = 3.09 + 0.74LTKI_t + 0.48LGNS_t$
$(5.35)^{***}$ $(29.66)^{***}$

4(i). $LIMPORTS_t = -11.59 + 0.53LTKI_t + 0.11LREER_{t-1} + 1.76LGDP_t$
$(1.43)^{*}$ (0.91) $(17.25)^{***}$

8(i). $LWAGES_t = 17.36 + 10.17LTKI_{t-1} - 15.58LLABOUR_t + 6.34LGNP_t$
$(7.43)^{***}$ $(9.32)^{***}$ $(5.65)^{***}$

Notes:

*** Significant at 1 per cent level

* Significant at 10 per cent level

References

Acs, Z.J. and D.B. Audretsch (1987). *Innovation, Market Structure and Firm Size*. Review of Economics and Statistics, Vol. 69

Bakhshi, Hasan and Yates, Tony (1998). *Are UK Inflation Expectations Rational?* London: Bank of England. Working Paper No. 81, July

Bank Negara Malaysia (1999). *Annual Report 1999*. Kuala Lumpur

Barba, Navaretti G. and Mattozzi, Andrea (1998). *Import of Technology and Export Performance*. Paper prepared for the UNU-INTECH conference on 'The Economics of Industrial Structure and Economic Innovation', Lisbon 16-17 October

Bartel, Ann and Sicherman, Nachum (1999). *Technological Change and Wages: An Inter-industry Analysis*. Journal of Political Economy 107(2)

Carr, David L., Markusen, James R. and Maskus, Keith E. (2001). *Estimating the Knowledge-driven Model of the Multinational Enterprise*. American Economic Review 91

Chan, Kalok, Hameed, Allaudeen and Tong, Wilson (1999). *Profitability of Momentum Strategies in the International Equity Markets*. Department of Finance, Hong Kong University of Science and Technology

Cowan, Robin (2001). *On the Variance of Market Innovation with the Number of Firms*. MERIT – Infonomics Research Memorandum series

Cyert, Richard and Mowery, David (1988). *The Impact of Technological Change on Employment and Economic Growth*. Cambridge: Ballinger Publishing Company

Economic Planning Unit (1999). *Malaysian Quality of Life*. Kuala Lumpur: Prime Minister's Department, Malaysia

Evenson, Robert E., Putnam, Jonathan, Kortum, Samuel (1989). *Invention by Industry*. Unpublished Manuscript. New Haven, Connecticut: Yale University

Evenson, Robert E. (1993). *Human Resources and Technological Development*, in C.D. Goodwin (ed.) International Investment in Human Capital. New York: International Institute for Education

Faust, Kulturzentrum and Schedle H. (1983). *International Patent Data: their Utilisation for the Analysis of Technological Development*. World Patent Information, Vol.5

Flor G. Alexander (2001). *ICT and Poverty: The Indisputable Link*. Paper presented in the forum on "Regional Economic Cooperation in Asia and the Bank, 11-14 June 2001, Bangkok

Ghosh, B.N. (1992). *Industrialisation and Labour Productivity in Malaysia: A Test of Verdoorn's Law*. Kuala Lumpur

Goodacre, Alan (1990). *Perceptions of Accounting Disclosures of R&D Expenditure: An Experimental Study*. Paper presented at the Institute of Quantitative Investment Research Autumn 1990 Conference, Cambridge

Goodacre, Alan and Tonks, Ian (1995). *Finance and Technological Change* in Stoneman (ed.) Handbook of the Economics of Innovation and Technological Change, Oxford, Blackwells

Greenwood, Jeremy and Jovanovic, Boyan (1999). *The IT Revolution and the Stock Market*. Cambridge: National Bureau of Economic Research

Grupp, Hariolf (1998). *Foundations of the Economics of Innovation*. Germany: Edward Elgar

Grupp, Hariolf and Schmoch, Ulrich (1992). *Perception of Scientification of Innovation as Measured by Referencing between Patents and Papers: Dynamics of Science-based Innovation*. Berlin

Harrigan, James (1995). *Technology, Factor Supplies and International Specialisation: Testing the Neo-classical Model*. Mimeo: University of Pittsburgh

Harris, Richard G. (2000). *The Knowledge-based Economy: Facts and Theories*. A paper presented at the MIER 2000 National Economic Outlook Conference, Kuala Lumpur

Hobijn, Bart and Jovanovic, Boyan (2000). *The Information Technology Revolution and the Stock Market*: The Federal Reserve Bank

Kaufer, Erich. (1989). *The Economics of the Patent System*. Chur: Harwood Academic Publishers

Keller, Wolfgang (2001). *International Technology Diffusion*. Cambridge: National Bureau of Economic Research

Krugman, Paul (1979). *A Model of Innovation, Technology Transfer and the World Distribution of Income*. Journal of Political Economy, 87

Lall, Sanjaya (1995). *Malaysia: Industrial Success and the role of the Government*. Journal of International Development, 7(5), September-October

Lall, Sanjaya (2001). *National Strategies for Technology Adoption in the Industrial Sector: Lessons of Recent Experience in the Developing Regions*. Background Paper for the United Nations and Development Programmes

Lim, Chee Cheng and Maisom Abdullah (2000). *Contribution of Private Foreign Investment in the Malaysian Manufacturing Sector 1977-1995*. Faculty of Economics and Management, University of Putra Malaysia

Loo, Ivo De and Ziesemer, Thomas (1999). *Determinants of Sectoral Average Wage and Employment Growth in a Specific Factors Model with Production Externalities and International Capital Movements*. Maastricht: Maastricht Economic Research Institute on Innovation and Technology, University of Maastricht

Meyer-Krahmer, F. (1984). *Recent Results in Measuring Innovation Output*. Research Policy, 13

Middleton, J., Ziderman, A. and Adams, A. Van (1993). *Skills for Productivity: Vocational Education and Training in Developing Countries*. New York: Oxford University Press

Mincer, Jacob (1996). *Economic Development, Human Capital and Wage Dynamics*. Journal of Economic Growth, Vol. 1

Mincer, Jacob and Danninger, Stephen (2001). *Technology, Unemployment and Inflation*. NBER Working Paper No. W7817

Ministry of Finance (various issues). *Economic Report*. Kuala Lumpur: Percetakan Nasional Malaysia Berhad

Ministry of Science, Technology and the Environment, Malaysia (1996). *1994 National Survey of Innovation in Industry*. Kuala Lumpur: Malaysian Science and Technology Information Centre

Ministry of Science, Technology and the Environment, Malaysia (2001). *1997-99 National Survey of Innovation*. Kuala Lumpur: Malaysian Science and Technology Information Centre

Moreno, Lourdes (1997). *The Determinants of Spanish Industrial Exports to the European Union*. Applied Economics, 29

National Productivity Corporation (2001). *Productivity Report 2000*. Kuala Lumpur

Niehans, Jurg (1981). *Economics: History, Doctrine, Science and Art*. Kyklos

Parente, Stephen L. (1995). *A Model of Technology Adoption and Growth*. Economic Theory, Vol. 6

Patel, Peter F. et al. (1995). *Localised Production of Technology for Global Markets*. Cambridge Journal of Economics

Pavitt, Keith (1984). *What Makes Basic Research Economically Useful?* Research Policy 19

Pesaran, H., Yongcheol Shin and Smith, Richard. (2001). *Bounds Testing Approaches to the Analysis of Level Relationships*. Department of Applied Economics, University of Cambridge

Ramachandran, R. (1999). *The Knowledge Imperative Index (KIX): A Measurement Model*. MIMOS: Kuala Lumpur

Romer, Paul M. (1994). *The Origins of Endogenous Growth*. Journal of Economic Perspectives, Vol. 8, No.1

Senhadji, Abdelhak (1998). *Time Series Estimation of Structural Import Demand Equations: A Cross-Country Analysis*. IMF Staff Paper. June 1998, Vol. 45(2)

Solow, Robert (1957). *Technical Change and the Aggregate Production Function*. Review of Economics and Statistics 39

Spiezia, Vincenzo and Vivarelli, Marco (1998). *Growth, Technical Change and Employment: Some Evidence from G-7 Manufacturing Industries*. TSER Working Paper

Stoneman, Paul (1983). *The Economic Analysis of Technological Change*. Oxford University Press

_____________ (1995). *Handbook of the Economics of Innovation and Technological Change*. UK: Blackwell

_____________ (2001). *Technological Diffusion and the Financial Environment*. Maastricht: The United Nations University, Institute for New Technologies

Symeonidis, George (1996). *Innovation, Firms Size and Market Structure: Schumpeterian Hypotheses and Some New Themes*. OECD

Teubal, Morris (2002). *What is the Systems Perspective to Innovation and Technology Policy and How Can We Apply it to Developing and Newly Industrialising Economies?* Journal of Evolutionary Economics, Volume 12, Number 1-2, March

Trefler, D. (1995). *The Case of the Missing Trade and Other HOV Mysteries*. American Economic Review, 85(5)

Tzannatos, Zafiris and Johnes, Geraint (1997). *Training and Skills Development in the East Asian Newly Industrialised Countries: a Comparison and Lessons for Developing Countries*. Journal of Vocational Education and Training, Vol. 49, No. 3

Wee, Victor Eng Lye (2002). *National Vision and Strategies of Malaysia*. Kuala Lumpur: Paper Presented at the International Forum on National Vision and Strategies

Wickramanayake, J. (2000). *Central Provident Fund and Savings in Singapore: An Empirical Analysis*. Monash University

Verdoon, J.P. (1980). *Verdoorn's Law in Retrospect: A Comment*. Economic Journal, 90