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THE DYNAMICS OF PRODUCTIVITY OF THE MANUFACTURING SECTOR

Abstract

This dissertation examines various determinants of productivity using different methodologies. First, it examines the effect of size on the performance of industries in Malaysia. Different proxies for size are used to see if it makes a significant difference to the results. Results show that: (1) annual sales turnover is a better measure for size because it is not biased to capital intensive and labour intensive industries, (2) the change in size of large industries seems to be able to explain more of the variations in output per labour compared to the medium and small ones. Second, it examines whether research and development has a long run relationship with total factor productivity of the manufacturing industries in the UK. R&D are decomposed into R&D capital by (1) the industry own enterprises, (2) other industries enterprises, and (3) foreign R&D capital. Panel unit root and panel cointegration tests are performed on a panel of 20 industries during 1980-2002. I find R&D and productivity to be cointegrated in the long run. The elasticities of productivity with respect to these R&D variables show that the industries significantly benefit from other domestic industries and foreign R&D but not their own. Third, it re-examines the direction of the causality between exports and productivity for Malaysian industries by using the error-correction and Granger causality models. By including other variables like size and capital intensity in my models, I have captured the indirect effects besides the direct effects between exports and productivity. I find that these industries support the export-led growth as well as the growth-driven export hypothesis. However, a further look into the results indicates that there is a possibility of an indirect causality between them through size and capital intensity.

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INTRODUCTION

1.1 Background of the Study

Productivity growth is important for long term growth prospects of a country as it structurally adjusts toward higher value-added production. As an important component to the economic growth, it has been subjected to numerous studies. These studies are either on the methods of measurement or the determinants of productivity at various levels of economic units within an economy or between countries. This dissertation focuses on the determinants of productivity and its dynamics in the manufacturing industries. Three studies are performed and presented in Chapters Two, Three and Four. Chapter Two focuses on size as a determinant to labour productivity in the Malaysia manufacturing industries, Chapter Three on research and development efforts as the determinant to total factor productivity in the UK manufacturing industries, and finally, Chapter Four on the causality of exports on productivity in Malaysia manufacturing industries. Chapter Three chooses the UK manufacturing industries as its subject of analysis due to its availability of data on R&D compared to Malaysia.

Improving its productivity has been one of Malaysia and the UK's main concerns. In the case of Malaysia, it's economy posted a productivity growth of 2.3% for the period 1993-2003, despite being affected by the Asian financial crisis in 1997-98. For the year 2003, Malaysia's productivity growth of 2.7% exceeded many of OECD countries, such as, the United States, 2.1%, the United Kingdom, 1.0%, Germany, 1.5%, France, 0.2%, Canada, -0.2% and Italy, -0.5%. Among Asian countries, Malaysia exceeded that of Hong Kong, 2.5%, Taiwan, 2.5% and Singapore, 0.7%. However, Japan and Republic of Korea recorded higher productivity growth of 2.8% and 3.7% respectively.

In Malaysia, the manufacturing sector continues to be a major contributor to GDP. It registered a productivity growth of 5.3% and output growth of 8.2% in 2003. The growth was attributed to higher capacity utilisation, with most industries, especially the export-oriented industries were operating at more than 88% of their capacity. With the increasingly global competition, Malaysia has participated more actively in trade, services and investment liberalisation at the multilateral, regional and bilateral levels. The government continue to improve the public sector delivery system by reviewing regularly procedures, processes and regulations in order to create an environment where businesses can flourish.

There are various ways of measuring the performance of the manufacturing industries. Mahadevan (2001) uses stochastic frontier approach on a panel data of 28 manufacturing industries over a period of 1981-1996 to assess the growth potential of the manufacturing sector. Besides total factor productivity, labour productivity is also frequently used to indicate performance of industries. Value added per employee and gross output per employee are used as proxies for productivity (NPC, 2002). Gross output based labour productivity measures are more sensitive to the degree of vertical integration and outsourcing than value-added based labour productivity measures (OECD, 2001)[1].

A review of the literature related to labour productivity found that labour productivity was higher in the export-oriented industries compared to the non-exporter ones in Taiwan (Hwang, 1989), and capital-intensive firms tend to have higher level of productivity compared to the labour intensive ones (Yokoyama,

[1] For instance, the labour productivity, measured at gross output, of industry A increases by 31.3% and industry B declines at 18%. The steep productivity rise in industry B reflects the fact that gross output hardly increases but less labour and more intermediate inputs are used. This has caused gross output per hour worked to rise very rapidly due to the substitution between primary and intermediate inputs. Thus, the increase in labour productivity does not come with increase in gross output and for each unit of labour, there is now a larger amount of intermediate input. On the other hand, labour productivity measured at value added, will reduce both labour input and value added, and therefore, reduces the sensitivity of labour productivity measures to the degree of vertical integration.

1991). In the UK, a study by Haskel and Martin (1993) showed that capital-labour ratio contributed 2.2 percentage point to the manufacturing productivity growth of 4.7%. In Malaysia, Ismail and Jajri (2000) in their study on 11 large scale industries, generally showed a positive capital-labour ratio contribution to the labour productivity growth rate.

In general, there are many studies on the sources of growth using single country data which include Ismail (1998) for Malaysia, Lau et al. (1993) for Brazil, and Liu and Armer (1993) for Taiwan. Studies that specifically focused on the manufacturing sector, for instance, Abdullah and Marshidi (1992), and Nik Mustapha (1998) found that the contribution of TFP to manufacturing output growth has been rather small. This is further supported by Ismail (1999) who studied the sources of growth in the SMIs manufacturing sector and found that in some industries, the contribution of TFP were still small especially in establishments that are labour intensive.

Looking at R&D efforts as a determinant of productivity, I find the UK has a longer history compared to Malaysia. Therefore, R&D efforts by industries in the UK manufacturing sector become the focus of my third chapter. R&D refers to efforts made by scientists, engineers, inventors and entrepreneurs who develop new knowledge and devise better ways of doing things and then reap the rewards when they are successful. From their innovation, they create advances in technology by inventing new products, improving existing products and reducing the cost of producing existing goods and services. Much research has been carried out in recent decades to assess the influence of research and development on productivity, mainly on developed economies and OECD countries.

Many economists, aware of the importance of R&D for innovation, have studied the relationship between R&D expenditure and productivity growth. There is now a large body of literature that provides theoretical as well as empirical models where cumulative R&D is an important source of technological change and productivity growth. Griliches (1995) notes that, both public investment in science and private investments in industrial R&D have been crucial contributors to world economic growth in the past and they are likely to continue in the future. However, the impact of R&D is not confined to the individual industry or country. There are evidence of the presence of R&D spillovers from other industries (Cameron, 2006; Bernstein, 1988) and foreign countries (Coe and Helpman, 1995; Guellec and van Pottelsberghe de la Potterie, 2001). It is found that the social return of R&D is more significant than the private return.

Another important determinant that this dissertation is focusing on is exports. How large is the effect of exports on productivity, and in what direction is the causality between them is still being debated in the literature. Early empirical studies, for example Balassa (1978a), and Feder (1983), test on the export-led growth hypothesis by adopting an augmented production function approach. In addition to the traditional inputs, capital and labour, they included export as a determinant to output. Besides these studies, many other studies found overwhelming evidence for the contemporaneous correlation between export growth and GDP growth. However, this contemporaneous correlation does not indicate causality. Further, the direction of the causality is also not identified. While output growth may cause export to grow, the opposite is equally plausible. Following this, recent empirical studies attempt to detect the causal link between exports and GDP by adopting the concept of causality by Granger (1969) and Sims (1972). Giles and Williams (2000), in their comprehensive survey, report differing evidences. These differing results might be due to the different time periods, frequencies, methods, variable selections and nonstationarity and (co)integrated properties. Therefore, an appropriate degree of caution must be considered before these results are interpreted (Yamada, 1998).

The causality tests will determine whether the variables have a uni- or bi-directional causality. While causality from exports to output is termed export-led growth (ELG), the reverse causal flow from output to exports is called grow-driven exports (GDE). Economic theory suggests exposure to greater competitive pressures could result in the more efficient use of existing resources, or interacting with other firms using best practice technology could result in the adoption of new processes or management practices[2]. This exposure may serve as a means to transfer technology from abroad and further generate spillover effects into the rest of the economy as efficiency improves and productivity grows.

Even though, our arguments show that the direction of causality is more towards exports causing productivity, the case for growth-driven export hypothesis is also important. This is because the exporting firms are mainly those that are productive, more profitable and successful, which make it timely for them to enter the exports market. If this is evident, the direction of the causality may go from productivity to exports. Growth-driven hypothesis suggests that those would-be exporters would prepare themselves to be more competitive and productive before they enter the exports market to ensure survival in the highly competitive export market.

In plant-level empirical studies, evidence show that before firms export, they improve their productivity and consequently make them more productive than those that do not intent to export. According to Lopez (2005), at least for the developing countries, the self-selection process may well be a conscious decision by which firms purposely increase their productivity with the clear intention of becoming exporters. Therefore, firms that enter the export markets are more productive than non-exporters. Besides that, the exporters are also found to be larger than the non-exporter. Learning effects are also found to be significant among new entrants.

[2] Greenaway & Kneller, 2004.

Whereas plant-level studies mainly study on export and productivity, country-level studies mainly study on trade or openness and growth. In country-level studies, the causes of the wide variation in economic growth rates between countries have been much debated. These disparities are found to be only in part explainable by different rates of increase in the employment of the basic factors of production, i.e. capital and labour (Kunst & Marin, 1989). Kunst & Marin concluded that the diversity in growth rates between countries are largely caused by different rates of increase in productivity per unit of factor input. The observed co-movement between productivity growth and export growth led to two causal hypothesis, i.e. export-led growth (ELG) hypothesis and the reverse causal flow, growth-driven exports (GDE) hypothesis. In the ELG hypothesis, export expansion stimulate output both directly, as a component of aggregate output, as well as, indirectly, through efficient resource allocation, greater capacity utilisation, exploitation of economies of scale, and stimulation of technological improvement due to foreign market competition (Awokuse, 2003). Through an expanded market base, export growth allows for the exploitation of economies of scale for open economies and promotes the transfer and diffusion of technical knowledge in the long run (Helpman & Krugman, 1985; Grossman & Helpman, 1991). Besides that, Balassa (1978b) and Buffie (1992) found that exports provide foreign exchange that allows for increasing levels of capital formation and thus stimulate output growth. On the other hand, GDE hypothesis, supported by the technology theories of trade, propose a causal link which runs from productivity to trade and not vice versa. These theories suggest that competitive performance in export markets are driven by market power which is mainly achieved through innovation (Vernon, 1966).

The idea of the export-led growth hypothesis is a recurrent one. Even though the new trade theories suggest a causal link between productivity and exports, the empirical evidence for ELG hypothesis is mixed. While the cross-section results appear to find a significantly positive and robust relationship, the time series evidence fails to provide uniform support to the ELG hypothesis. Similar to the wide variations in the findings of the literature mentioned, studies on Malaysia also show differing results. As found in most cross country studies, Ram (1987), Salvatore & Hatcher (1991), Amirkhalkhali & Dar (1995) and Dhananjayan & Devi (1997) find export to have a positive relationship with growth in Malaysia. While Ahmad & Harnhirun (1992), Arnade & Vasavada (1995), Ahmad et al (1997) and Xu (1996) find Malaysia to have growth-led export, Dodaro (1993) and Ghatak et al (1997) find Malaysia to have an export-led growth. Doraisami (1996) and Pomponio (1996) find export and growth to have a bi-directional causality. On the contrary, Bahmani-Oskooee & Alse (1993), Riezman et al (1996) and Islam (1998) find export and growth are not cointegrated, and therefore, find no long run relationship between these two variables.

1.2 Objectives of the Study

The main objective of this dissertation is to identify the determinants of productivity in the manufacturing industries. I analyse the significance of size, export, research and development, capital intensity, intermediate materials and economic performance as potential determinants of productivity of industries in the manufacturing sector. This dissertation contributes to the literature by conducting three empirical investigations which can be specified into the following objectives:

i. to examine the effect of size on the performance of industries and determining the best proxy for size as a determinant of labour productivity;

ii. to evaluate whether research and development has a long run relationship with total factor productivity taking into account the different sources of these R&D efforts;

iii. to re-examine the causality between exports and labour productivity and investigate whether the industry results confirm the country level findings.

1.3 Motivations

A great number of empirical studies on the determinants of productivity have dealt with the sources of productivity growth and measuring the rate of their contribution to productivity growth. While many studies use macro and firm level data, there are limited studies that use a detailed category of industries. This motivates me to use industry level data in all my empirical chapters to shed more light on what the panel of industries might indicate in comparison to studies made at country and firm level. Further, industry level data will minimise the aggregation problem suffered in macro data and reduce selection bias in firm level data. More often than not, the selection of firms are made out of convenience of getting the data and based on their performance in the industry. This problem is aggravated when their sample does not adequately represent the whole population.

In examining the impact of size on the performance of industries, I find different studies use different measures as a proxy to size. In the case of Malaysia, either in academic contributions or government agencies, paid-up capital and the number of employees are frequently used rather than annual sales turnover. To date, there is no literature that compares the effect of using different measures of size as a determinant to labour productivity. Identifying an effective measure of size that significantly affects the performance of industry is useful in identifying an effective measure of firm size and how size will affect their performance.

This dissertation also looks into the importance of R&D as a determinant of productivity due the growing importance of innovation and technology to productivity and economic growth in the long run. As many contributions are based on country level and firm level data, I use industry level data to analyse whether the industry data behaves similarly with the firm and country level data. I found the industry R&D does not behave in a similar way as the country level R&D in relation to total factor productivity.

Besides the R&D efforts and the growing globalisation activities around the world, it is important to look at exports as a determinant of labour productivity. It is also subjected to questions about which direction does the causality runs. Does exports cause productivity, or vice versa? As the literature frequently use country level data, I investigate on industry level data, using error correction and Granger causality models.

1.4 Contributions of this Dissertation

In Chapter Two, I examine how the average size, measured by employment, of firms in an industry may affect the growth or performance of the industry. The size distribution is divided into 3 groups, i.e. small, medium and large industries. For this purpose, I apply Solow growth model, as used by Mankiw, Romer and Weil (1992). In their model, labour productivity of a country is the dependent variable. They use it as a measure of the standard of living. As labour productivity is also used as an indicator of the industry performance, this model is adapted to our industry level data. I am using the data on 73 industries, at 4-digit ISIC[3] level, from 1980-1999 for Malaysia.

The contribution of this chapter to the present literature is, it identifies the correct and unbiased measure for size that is consistent to the economic theory. This chapter identifies annual sales turnover as the best measurement for size because it is unbiased to capital intensive and labour intensive industries. My results also

[3] International Standard of Industrial Classification.

prove that it is consistent to the economic theory which states that size of industries grow with the performance of the industries. As far as I am aware of, no effort has been made to compare how different measures of size may affect the industries performance in different ways. As the performance of industries is the main concern to all economies, the correct measure of size, which is an important determinant of industry performance, is a relevant issue to address.

In Chapter Three, I examine whether R&D has a long run relationship with total factor productivity (TFP). As the literature mainly use macro data and firm level data, I explore the industry level data to see if it confirms the earlier findings made from macro and firm level data. In addition to a country's own R&D and foreign R&D in the macro data model, I use the industry R&D and other domestic industrial R&D to obtain the information on how far an industry R&D capital influence its productivity and how far it benefits from R&D spillovers from other industries. It is the objective of this study to identify whether R&D accumulated expenditure and TFP are significantly related in the long run. The R&D expenditure of other industries within the sector and those from foreign countries are also analysed as a way to establish a spillover effect from other industries within the economy and other economies. My results provide evidence that the manufacturing industries in the UK benefit from other domestic industries R&D and foreign R&D spillovers but not their own R&D activities.

In Chapter Three, I contribute to the existing literature by providing an insight into the possible economic reason for the UK industry R&D results that contradicts country level findings. Unlike the positive impact of domestic R&D on TFP at country level, the industry R&D has a negative impact on its TFP. This result proves the industry does not rely on its own R&D to improve its productivity but rather the collective R&D efforts of all industries in the economy. Even though the industry's R&D is a cost to the industry, it is still crucial for each industry to perform their R&D due to its social returns. Due to its public good nature, other industries seem to be benefiting collectively from the R&D efforts of domestic industries within the economy. This makes it important for every industry to pursue their R&D efforts even though it has a negative impact on its own industry.

Chapter Four re-examines the causality between productivity and exports in the case of Malaysian manufacturing industries for the period of 1980-1999. It reaffirms whether these variables have a unidirectional or bidirectional causality. Analysing the direction of causality of export and productivity is important in determining whether there is a feedback in their causality. My results provide evidence that the variables have a short-run as well as a long-run unidirectional causality from export to productivity.

Chapter Four contributes by examining whether industry level data support the country level findings. Capital intensity (the ratio of capital stock to employment) and average size (the ratio of real gross output to number of establishments in the industry) variables are included in the model as other possible variables that can influence both or either export or productivity, and directly or indirectly. Even though productivity does not cause export, there is a possibility of an indirect causality through size, as productivity cause size and size, in turn cause export.

1.5 Outline of the Dissertation

This dissertation is concerned with the study of productivity, its determinants, their long run relationship and causality. It revolves around three main empirical analyses found in Chapter Two, Three and Four. As this dissertation does not devote a chapter for literature review alone, each of these chapters will contain their own brief literature review relevant to their objectives. All these chapters adopt panel data analyses. The organisation of the dissertation is as follows:

Chapter 2 examines the effect of size on the performance of industries in the manufacturing sector. By employing an augmented Mankiw, Romer and Weil (1992) model, this chapter extend its analysis to capital intensity, employment, economic performance and technological progress from the size perspective. The model also control for export and intermediate material. The data are described after the methodology section. This is followed by the empirical results and the conclusion.

Chapter 3 is an empirical test of the impact of R&D on total factor productivity in the long run. Due to limited data on R&D on Malaysia industries, the UK data is used. Different sources of R&D efforts are examined, i.e. the industry own R&D, other domestic R&D and foreign R&D. To avoid spurious regressions, I performed panel unit root tests by Levin, Lin and Chu (2002) and Maddala and Wu (1999), and cointegration tests by Kao (1999) and Pedroni (1999). I further check for robustness in my results by testing on the impact of R&D on labour productivity and value added. The outcome is discussed in the results and discussions section. The study is concluded in the final section.

Chapter 4 attempts to establish the causality of export, capital intensity and size on labour productivity in Malaysia. It mainly tests on export-led growth and growth-led export hypotheses on the industries in the manufacturing sector. Capital intensity and size are included in the model to see if it affects the results on exports and productivity. Panel unit root and cointegration tests are performed before the error correction mechanism is carried out. The results from the error correction model are compared with those of Granger bivariate and multivariate causality models. The last section concludes on the chapter.

Chapter Five concludes the dissertation by summarising the major findings and policy implications that can be derived from the empirical chapters. Lastly, due to the limitations of the studies that I have performed, I recommendation further works to follow up on what this dissertation and other work have done. Econometric procedures applied in the chapters are provided at the end of the dissertation.

DOES SIZE MATTER IN DETERMINING THE PERFORMANCE OF MANUFACTURING INDUSTRIES?

Abstract

This chapter examines the effect of size on the performance of industries within the economy. In a panel setting, it applies the augmented Cobb-Douglas model used by Mankiw et al. (1992) on 73 manufacturing industries in Malaysia for the period 1981-1999. Fixed effect is applied to levels and first difference data. Different proxies for size are used to see if it makes a significant difference to the results. Results show that: (1) annual sales turnover is a better measure for size because it is not biased to capital intensive and labour intensive industries, (2) only the medium and large industries are found to have cyclical pattern, and (3) the change in the size of the large industries seems to be able to explain more of the variations in output per labour compared to the medium and small ones.

JEL Classification: J24, L25, L60, C23
Keywords : Industries Performance, Determinants, Size, Cyclical Pattern, Panel Data.

2.1 Introduction

This chapter examines how the average size, measured by employment, annual sales turnover and paid-up capital of firms in an industry may affect the growth or performance of the industry. The size distribution is divided into 3 groups, i.e. small, medium and large industries[1]. For this purpose, I apply Solow growth model, as used by Mankiw, Romer and Weil (1992). In their model, labour productivity of a country is the dependent variable. They use it as a measure of the standard of living. As labour productivity is also used an indicator of the industry performance, this model is adapted to our industry level data. I am using the data on 73 industries, at 4-digit ISIC[2] level, from 1980-1999 for Malaysia.

Size distribution and growth of firms become the focus of sustained research effort since the 1950s. Early studies are mainly time series studies, which include

[1] See Gibrat (1931) and Mansfield (1962).
[2] International Standard of Industrial Classification.

the works by Hart and Prais (1956), Simon and Bonini (1958), Mansfield (1962), Ijiri and Simon (1964, 1977), Samuels (1965), Prais (1976) and Lucas (1967, 1978), among others. By mid 1960s, a second research literature that uses cross-sectional data emerged. The works by Bain (1966), Pryor (1972) and Philips (1971), for instance, were motivated by the observation that market structure of industries varies in a systematic way with such variables such as scale economies, R&D and advertising. In this period, stochastic growth models were developed based on the paper by Ijiri and Simon (1977). In the late 1970s, the cross-sectional literature has been reformulated using game-theoretic models (see survey by Sutton, 1997). Following this, is the revival of interest in the older growth-of-firms literature (Jovanovic, 1982; and Selten, 1983).

More recent works like Kumar (1985), Hall (1987), Evans (1987), Acs & Audretch (1990) and Farinas and Moreno (2000) that use more complete datasets than in the past proved that the relationship between growth and size is not constant but rather decreasing. Farinas and Moreno (2000) in particular, find the mean growth rate of successful firms decline with size and age. While Kumar (1985) and Acs and Audretch (1990) found that smaller firms grow faster than large firms, earlier studies by Samuels (1965) and Prais (1976) reported the opposite tendency. This tendency partly reflects the role played by growth through acquisition among larger firms (McCloughan, 1995).

Studying on the impact of size on the performance of an industry may be useful given that its minimum efficiency scale is known. However, as the minimum efficiency scale vary from industry to industry depending on the nature of their cost structure, our industry data will not do justice to this issue. Further, the minimum efficiency scale of one country would be expected to differ from other more or less develop countries due to their technology and market variation. Hence, it is not the focus of my study to look into this issue. Instead, I group the industries by their relative sizes, i.e. small, medium and large, to see how their size group may have any significance to their performance.

The contribution of this chapter to the present literature is, it identifies the correct and unbiased measure for size that is consistent to the economic theory. As there are a few definitions of size, there is a need to identify which is most appropriate to describe the relative sizes of industries in the manufacturing sector. This chapter identifies annual sales turnover as the best measurement for size because it is unbiased to capital intensive and labour intensive industries. My results also prove that it is consistent to the economic theory which states that size of industries grow with the performance of the industries. As far as I am aware of, no effort has been made to compare how different measures of size may affect the industries performance in different ways. As the performance of industries is the main concern to all economies, the correct measure of size, which is an important determinant of industry performance, is a relevant issue to address.

In the following section, the empirical framework and methodology is set out. Details of the data, summary of statistics and Pairwise correlation are given in Section 3 and results are presented and discussed in Section 4. Summary and conclusions follow in Section 5.

2.2 Empirical Framework and Methodology

This study adopts the framework introduced by Mankiw, Romer and Weil (1992) (MRW). MRW assume a Cobb-Douglas production function in their Solow model and develop an output per labour variable on the left side of the equation. In their paper, the following production function is considered:

$$Y_t = K_t^{\alpha} H^{\beta} (A_t L_t)^{1-\alpha-\beta} \tag{2.1}$$

where Y is real gross output, K is the stock of physical capital, H is the stock of human capital, L is employment, A is a labour-augmenting factor reflecting the level of technology and efficiency in the industry, and the subscript t refers to the time period in years. It is assumed that $\alpha + \beta < 1$, so that there are constant returns to factor inputs[3] when applied jointly, and decreasing returns when applied separately.

In Solow growth model, labour (L) and labour-augmenting technology (A) are assumed to grow exogenously at rates n and g:

$$L_t = L_0 e^{nt} \tag{2.2}$$

and

$$A_t = A_0 e^{gt} \tag{2.3}$$

where n is the exogenous rate of growth of the labour force in the industries, A is the level of technology, g is the rate of technological progress. The number of effective units of labour, $A_t L_t$, grows at rate $n + g$. L_0 is normalised to 1 for simplicity. Following Knight, Loayza and Villanueva (KLV) (1993), I assume labour-augmenting technology (A_t) to grow according to the following:

$$A_t = A_0 e^{gt} F^{\theta_F} P^{\theta_P} \tag{2.4}$$

where F is the degree of openness of the domestic economy to foreign trade and P is the level of government fixed investment in the economy. I adjust my variables to industry level data, since I am not looking into country level data as in KLV. I use exports instead of the degree of openness, as all industries are subjected to the same level of openness, and industry fixed assets capital instead of government fixed investment. I use this industry fixed assets capital as one of the proxies to

[3] Equation (2.1) assumes that capital and labour are paid their marginal product.

the average size of establishments in each industry. Besides that, I observe intermediate materials and economic performance due to their potential importance to the industries' performance. Equation (2.4) will now be written as

$$A_t = A_0 e^{gt} X^{\theta_X} S^{\theta_S} M^{\theta_M} D^{\theta_E} \tag{2.5}$$

Where X is exports, S is size, M is the intermediate materials used in production and D is a dummy variable used to capture economic performance within an industry. Thus, my efficiency variable, A_t, differs from that used in MRW, in that it depends not only on technological improvements but also on intermediate materials that are used in the production process, economic performance, exports, and average size of firms within the industry. I believe that this modification is relevant to the empirical study of industrial growth in either developing or developed economies, where technological improvements tend to take into account these factors as sources of labour productivity growth.

Further, MRW model specify s_k as the fraction of income invested in physical capital, s_h is the fraction invested to human capital and $(n+g+\delta)$ as population growth. They come up with the following equation:

$$\ln\left(\frac{Y_t}{L_t}\right) = \ln A_0 + gt + \frac{\alpha}{1-\alpha-\beta}\ln s_k + \frac{\beta}{1-\alpha-\beta}\ln s_h - \frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) + \varepsilon_t \tag{2.6}$$

Equation 2.6 indicates the steady state output per worker or labour productivity[4]. The terms $\frac{\alpha}{1-\alpha-\beta}$, $\frac{\beta}{1-\alpha-\beta}$, and $\frac{\alpha+\beta}{1-\alpha-\beta}$ in this equation represent the elasticities of per capita income with respect to the fraction of income invested in

[4] As this is a static model, it will not capture the future or the past expected impact of a change in one or more independent variable(s), as in a dynamic model.

physical capital, the fraction of income invested in human capital and labour growth, respectively. Mainly due to data limitations, this chapter assumes s_h and gt do not vary over time and s_k is defined as the capital-labour ratio. This means that $\ln A_0$, s_h and gt are included as a constant term in A_0 in equation (2.7). I transform A_t in equation (2.5) into natural logarithm and incorporate it into equation (2.6). In a panel data setting, I will obtain the following equation:

$$\ln y_{it}^{\bullet} = A_0 + \theta_1 x_{it} + \theta_2 s_{it} + \theta_3 m_{it} + \theta_4 d_{it} + \theta_5 \ln k_{it} - \theta_6 \ln(n+g+\delta)_{it} + u_i + v_t + e_{it} \quad (2.7)$$

where $i = 1, \ldots, 73$
$t = 1981, \ldots, 1999$

y = real gross output (constant at 1987 prices) divided by labour

x = exports

s = average size (paid-up capital/ number of employees/ sales turnover)

m = intermediate materials and services

D = economic performance dummy

k = capital-labour ratio

$(n+g+\delta)$ = n is labour growth, g is industry growth and δ is depreciation of physical capital stock

u_i = industry specific effect

v_t = time specific effect

e_{it} = overall error term, assumed to be identically and independently distributed

A_0 is a constant term and $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$ and θ_6 are parameters to be estimated. i represents 73 industries at four-digit ISIC level in Malaysia, and t represents the time period in years, from 1981 to 1999. Similarly to MRW, I assume $(g+\delta)$ to be constant over time and across industries at 0.07, primarily reflecting the advancement of knowledge, which is not industry-specific[5].

As I am using industry level data, I redefine labour productivity in the context of an industry. Both MRW and KLV use output per labour in their models to indicate standard of living, as they are looking at the cross-country data. However, this study uses this variable to indicate the performance of industries.

Equation (2.7) provides the basis for the empirical model to be estimated for the rest of this chapter. To capture the effect peculiar to the specific time period or industries on productivity growth, I transform the continuous variables to first difference. The dummy variables are not first differenced. If the economic performance dummy is first differenced, it will not capture the full effect of the dummy, but rather the point where there is a change between the zeroes and ones in the dummy variable. By doing this transformation, I will provide different information in my results relative to growth. To compare their relative results, each model is estimated both at levels and at first difference. Besides that, I also perform robustness checks on other definitions of size to find out if different definitions[6] or proxies for size make any difference to the results.

2.3 Data Description

The dataset was produced by UNIDO and can be obtained from the Manchester Information and Associated Services (MIMAS) website. Unbalanced short panel data is used due to some missing data for some years. The time period covers nineteen years, 1981-1999. For detailed description of data and how they are constructed, refer to Appendix 2.I.

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[5] This rate is higher than Mankiw, Romer and Weil's rate of 0.05, considering the high average growth rates of 0.047 in the manufacturing output during the period and depreciation cost assumed to be 0.023 per year. Therefore, 0.047+0.023=0.07.

[6] For different definitions of sizes applied in Malaysia, see Appendix 2.III.

The four-digit industries[7] dataset is in the form of panel data, since they have both the time-series and cross-sectional dimension (across years and productive industries). Even though it generates a problem of comparability across units, due to greater degrees of freedom and additional structure from the broader dataset, it tends to generate efficiency in estimation. Below is the summary of the main variables used in the model. Only continuous variables are shown. In the case of economic performance, D, the industrial production index growth is shown instead of the dummy variable in the model, to give a brief idea of the variable that we are using.

**** Insert Table 2.1 ****

Table 2.2 presents Pairwise correlations of all variables. This is consistent with the economic theory whereby each unit of these variables contributes positively to output and labour productivity.

**** Insert Table 2.2 ****

Labour productivity (LP) in the Malaysian manufacturing sector had been increasing over time except in the recession period of 1996 to 2000. Even though LP suffered negative growth during the mid-1980s recession, the Malaysian economy was worse hit by the financial crisis in 1998. This has caused a negative 3.15% in the annual average growth of LP during the period 1996-2000.

**** Insert Table 2.3 ****

[7] See Appendix 2.IV.

The trend of LP growth from 1982 to 2000 is shown in Figure 2.1. The trend implies that there is a tendency for the labour productivity growth to be influenced by economic growth, bearing in mind the economic performance during the mid 1980s and 1998. It is possible that there is a cyclical pattern in the labour productivity growth in Malaysia.

**** Insert Figure 2.1 ****

During the period under study, real gross output/labour shows a steady increase throughout the years with a noticeable increase between 1994 and 1996 (Figure 2.2). From 1997 onwards, it shows a declining trend due to the economic recession.

**** Insert Figure 2.2 ****

Looking at the distribution of labour productivity by average size[8], it is evident that the industrial chemicals and petroleum refinery industries (ISIC 35) noticeably have higher labour productivity (US$940,236.5) compared to others (see Figure 2.3). This is followed by the fabricated metals, machinery and equipments industry (ISIC 38, US$230,877.4). The rest of the industries, on average, are below US$143,000.0, with 'other manufacturing industries' (ISIC 39, US$17,833.0) at the lowest.

[8] Firm size is based on the number of full-time workers employed in a firm. In the next section, other definitions of firm size will also be used, for instance, based on the fixed asset capital or sales turnover of each firm. See Appendix 2.II.

**** Insert Figure 2.3 ****

2.4 Results and Discussion

First of all, I need to determine whether it is efficient to either use fixed or random effect in my regressions. To begin with, I apply OLS estimation on equation (2.7), i.e. without the fixed effects. The OLS residuals, ε_{it} , is tested for random effect using the Breusch and Pagan Lagrangian Multiplier (LM) test. The LM is distributed as χ^2 with one degree of freedom under the null hypothesis which states that there is no industry specific effect. I find the calculated χ^2 value exceeds the tabulated value, which suggests that the null hypothesis is rejected and there might be industry-specific effects in the data. Because of this, pooled OLS model will provide inefficient estimates on the coefficients and invalid OLS standard errors. Hausman specification test for equation (2.7) suggests that fixed effect is appropriate because the p-value is too small.

As this chapter examines whether the size of firms has an impact on the industry's performance and growth, I focus on the impact of annual sales turnover besides other proxies like paid-up capital and the number of employees, on the industry's performance. Table 2.4 shows that *s*, defined as the annual sales turnover (gross output), has a positive coefficient, which suggests that the growth of manufacturing output (size) improves the industry performance. This result confirms the Verdoorn's Law which states that the growth of production is closely related to labour productivity. In the same way, this suggests that the mean (labour productivity) growth rate of firms declines with size, and in line with other works by Hall (1987), Evans (1987) and Farinas and Moreno (2000).

**** Insert Table 2.4 ****

There is a significant cyclical pattern for the whole panel at level, however, at first differenced[9], it is not significant at all. At level, the economic performance has a negative coefficient, which may imply a negative growth in the industry affects the labour productivity in a negative way. Refer to Appendix 2.I for description of this economic performance dummy variable.

Export is significant in determining labour productivity in both panel (1) and (2). Further, my results indicate that there is an important role played by capital intensity (capital-labour ratio) and intermediate material in determining labour productivity. This requires investment in appropriate technology, and good quality materials to be in place, in order to provide the impetus for sustainable industry performance.

Following the regressions are the diagnostic tests. I use variance-inflation factor (VIF) to diagnose multicollinearity problems. The tests suggest that the regressors are neither correlated across time and industries nor do they have linear relationship among them in all the models. The F statistics and Wald χ^2 of all regressions in Tables 2.4 to 2.9 show that the independent variables have a statistically significant relationship with the dependent variable. The Ramsey tests (Ramsey, 1969), on the other hand, mainly reject the null hypothesis of correct functional form. Only the Ramsey test on the small industries regression at level (Table 2.4) suggests that I cannot the reject the null hypothesis. , As a panel dataset, the R^2 from the cross section and within estimates are reported. The R^2 results suggest that the variations in the time series and across industries reasonably explained the variations in the industries performance.

[9] As this is not a thoroughly first differenced model because I did not first difference the dummy variables, I maintained the constants in the regressions.

2.4.1 Average size of industries

I further investigate whether my results are robust across different categories or sub-panels of industries that are considered as small, medium and large on average. I am examining whether the hypothesis that mean growth rate declines/increase with size is true for all size subgroups. For this purpose, the dataset is divided into three subgroups based on their relative industrial average size and specified as small, medium and large. To create these subgroups, the dataset is stratified by their average size and separated at 40% and 70% percentiles. This means, the small size industries consist of industries that are the first lowest 40%, whereas the medium size industries consist of those between 41% to 70% percentile ranges. The large size industries consist of those from the highest 30%.

Firstly, I use average annual sales turnover as the proxy for size, s, and the basis to create subgroups of small, medium and large industries. The results are shown in Table 2.5. Size consistently shows a significant positive impact on labour productivity. At first difference, there is a noticeable pattern among the size subgroups where I find the larger the industries, the bigger is their effect on the performance of industries. As annual sales turnover is used as an indicator for the scale of operation, it also reflects the actual market size the industries are catering to and provides an idea of the investment returns. A larger market size ensures returns on new market investments (Bhavani, 2001). Therefore, industries that have a large scale of operation would have the advantage of exploiting new technologies compared to the smaller ones. As technology replaces human labour, less workers are employed. This is particularly evident in the large industries. Capital-labour ratio and intermediate materials remain important and significant in influencing the industries performance at all sizes.

**** Insert Table 2.5 ****

Secondly, I use average number of employees as the next proxy to size. This is to check for robustness of the results in Table 2.5. The results in Table 2.6 provide evidence that the sign of the coefficients for size is not robust with my earlier results when annual sales turnover is used (Table 2.5). The negative sign for size means that as more people are employed, labour productivity will decline[10]. If this is true, it implies that downsizing and improving the efficiency of labours may be required to improve the performance of industries in Malaysia. However, these results contradict with the marginal productivity of labour theory where a labour will only be employed if he contributes more than what he is earning. The fact that size is negatively associated with labour may imply an outcome of a bias. When size is associated with labour force, there is a risk that a small labour intensive industry may look more important than the one which is capital intensive and has bigger assets or sales. On the other hand, when size is associated with average gross output, which is used as a proxy to annual sales, it is unbiased because it does not favour either capital or labour intensive industries. In this case, Table 2.5 seems to provide more reliable evidence that is consistent to the economic theory.

**** Insert Table 2.6 ****

Contrary to size, other regressors in the equation like capital-labour ratio and intermediate materials remain positively significant to industry performance for all industry sizes both at levels and first difference. Further, the capital-labour ratio of large industries contributes more to labour productivity compared to smaller industries. This supports the findings in Othman and Mohamad (1995).

[10] Similar results are obtained in the case of the UK and US in van Ark and Monnikhof (1996).

Even though large industries show the highest estimates compared to small and medium industries, it shows much lower estimates at first difference, probably due to the fact that they are capital-intensive already. Increase in capital intensity will not improve labour productivity as much as the small and medium industries.

Finally, I use fixed assets capital to identify the size of industries (Table 2.7). When fixed assets capital is used as a proxy for paid-up capital, the results are similar to those in Table 2.6. A possible explanation to these results is that the small firms may have higher labour productivity and low transaction costs, since they are, in most cases, family firms. Besides that, some of the small firms may have employed skilled labours, which may have account for the bias estimates.

**** Insert Table 2.7 ****

2.4.2 Different periods

Following Pugno (1995), I regress equation (2.7) in subperiods of five-years. This is to check for the stability of my results over these subperiods. The results are shown in Table 2.8.

**** Insert Table 2.8 ****

Size (based on annual sales turnover), capital-labour ratio, intermediate material and labour growth mostly show significant coefficients, both at level and first difference, except for some periods. Thus, many of the subperiods support the estimates of the overall period, with the main exception of the economic performance dummy, D, for all panels. Other exceptions are capital-labour ratio, which is not significant for the 1991-95 period at level and intermediate material that tends to be insignificant during the periods when economic recessions occurred, i.e. 1986-1990 and 1996-99. It is only significant during periods when there is no economic recession. Throughout the period, $(n+g+\delta)$ is negative as expected, similar to the MRW results. Exports for the most part are negatively significant at level, however, at first difference, exports on the whole, are insignificant.

The overall R^2 for the whole period is between 0.55 and 0.88, except for the period 1991-95 at level, which is much lower at 0.29. This shows that the regressions explain quite well the variations in labour productivity. This is further supported by the F-statistics that show p-values of almost zero for all regressions. In most cases, the time variations are able to explain the variations in labour productivity compared to the cross-industries variations. In other words, the overall R^2 mostly come from the variability within the industrial groups.

2.4.3 Industry level

Following Ghura and Hadjimichael (1996), I use dummies to identify different subgroups based on their characteristics. The panel is identified by 14 subgroups[11] to account for possible fixed effects stemming from the fact that they are similar industries by category. The choices of these industries subgroups are made based on their significant contribution to total output growth. From these subgroups, the impact of each industry at two- to three-digit level on labour productivity is examined. In Table 2.9, the main variables show similar estimates with those in Table 2.8. From the Wald χ^2 statistics, all variables in the regressions are found to be jointly significant in explaining the variations in labour productivity. All the main explanatory variables remain significant at 1% level. Even though panel (1) show all of the industry dummies are insignificant at 5% significance level, I find D33 and D35 industries to be significant, at 10%

[11] See Appendix 2.V for the list of industries at two-digit and three-digit level.

significance level. For this reason, I disaggregate D33 and D35 from two-digit ISIC level, to three-digit ISIC level in panel (2), to identify the source of this significance. In this panel, within industry D33, only wood products (excluding furniture) (D331) is significant at 10%, but both D331(wood products) and D332 (furniture) are insignificant at 5% significance level. In industry D35, petroleum refinery (D353) is the major contributor to labour productivity, with its labour productivity 1.61% higher than the rest and coefficient estimate significant at 1% level. This is probably due to the fact that it is a very capital-intensive industry. This is followed by industrial chemicals (D351), significant at 1% level, and 'other chemicals' (D352) significant at 10% level. Plastic industry (D356) and rubber industry (D355), on the other hand, are not significant. In this panel, exports seem to be significant at 1% level when regressed with the two- and three-digit industry dummies.

**** Insert Table 2.9 ****

Panels (1) – (2) are rerun at first difference[12], as shown in panel (3) and (4). In the first difference models, the dummy variables for industries subgroups did not seem to capture significant specific characteristics that might be identifiable within common industries categories. Even so, the results on other variables remain similar between these two panels and the base model in Table 2.8. As can be observed, exports are significant at 5% significance level, whereas economic performance is not significant at all, even though it is significant at 1% significance level in levels estimates.

All the panels show that the variables are jointly significant in determining the variations in labour productivity growth. Most of the variability in labour productivity (i.e. at levels) are explained by the cross-section variations, rather than the within variations. In contrast, most of the variability in labour

[12] Only variables that are in natural logarithm are transformed to first difference.

chemicals industries contribute significantly to labour productivity. Generally, the industries are found to be cyclical except for the small ones.

In growth terms, the change in the size of large industries seem to be able to explain more of the variations in labour productivity growth due to the fact they contribute more to the gross output of the manufacturing sector. Similarly, capital-labour ratio and intermediate materials tend to show higher coefficients compared to levels. However, economic performance is found to be insignificant and the industry dummies generally do not explain the variations in labour productivity growth. Large industries do not respond as well as the small and medium industries when it comes to capital-labour ratio and intermediate materials. Labour productivity growth is more responsive to changes in these two variables. Since the manufacturing sector has generally recorded an increasing trend in labour productivity, this means firms' level of employment has decreased during the period. This shows that firms are generally cautious about increasing employment, particularly when it is at the risk of reducing their labour efficiency and productivity. Concurrent to the Malaysian government implementing its Vision 2020 policy, aimed at becoming a developed economy by the year 2020, the results from this study show that the industries are moving in the right direction in improving the performance of labour, and therefore, their firms.

TABLES AND FIGURES

Table 2.1 : Descriptive Statistics

Variable	Description	Obs	Mean	Std. Dev.	Min	Max
Y	Labour Productivity	1367	59.9	146.4	2.8	2,736.4
M	Intermediate Materials	1373	407,912	1,343,560	0	18,782,000
D	Economic Performance	1296	8.7	17.4	-52.1	146.2
K	Capital-Labour Ratio	1232	62.3	91.0	0.7	738.1
X	Exports	1089	293.9	1,460.4	0.041	19,500.5
$(n+g+\delta)$	Labour Growth	1302	0.14	0.45	-0.91	10.40
S	Firms Average Size	1367	8,044	24,899	28	323,473

Notes: Y, M, K and X are in '000 real US\$. $(n+g+\delta)$ is in %, and S is the average annual sales turnover per establishment.

Table 2.2 :
Matrix of Pairwise Correlation Coefficients for Pairs of Variables

Variable	Y	M	D	K	$(n+g+\delta)$	S	X
Y	1.000						
M	0.1374	1.000					
D	-0.0694	-0.0291	1.000				
K	0.2942	0.0029	-0.0775	1.000			
$(n+g+\delta)$	-0.0022	-0.0014	-0.0774	0.0546	1.000		
S	0.7951	0.2147	-0.0408	0.3659	0.0223	1.0000	
X	0.0533	0.9685	-0.0073	-0.0167	-0.0028	0.1638	1.0000

Table 2.3 :
Labour Productivity in the Manufacturing Sector, Malaysia, 1970-2000

Year	Real Gross Output ('000)	Employment	Labour Productivity(LP)	Growth Rate of LP *
1970	3,023,898	170,918	17,692.1	-
1975	7,850,253	306,619	25,602.63	8.94
1980	15,802,613	499,083	31,663.3	4.73
1985	17,700,100	473,300	37,397.21	3.62
1990	31,526,143	830,700	37,951.3	0.29
1995	73,843,462	1,369,000	53,939.71	8.42
2000	70,915,104	1,560,706	45,437.84	- 3.15

Note :
(1) Labour productivity - Real Gross Output Employment
*(2) * Annual average growth rate*
Source: Generated from UNIDO database.

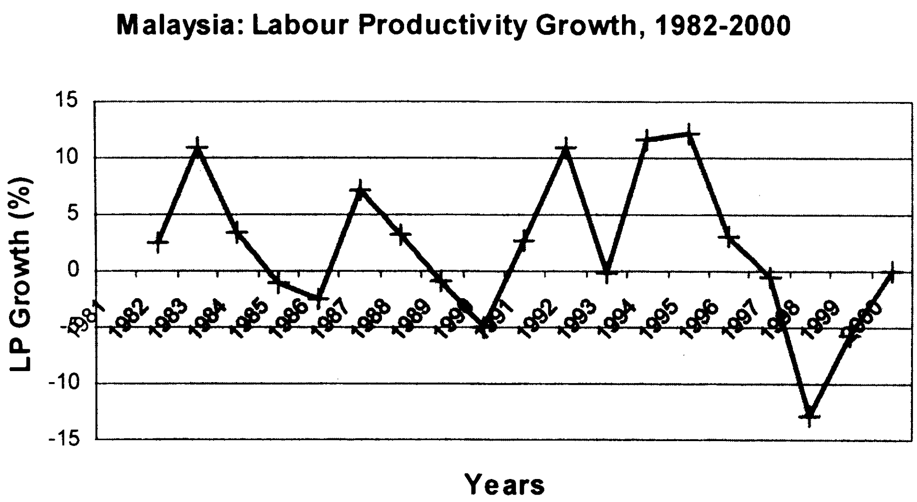


Figure 2.1

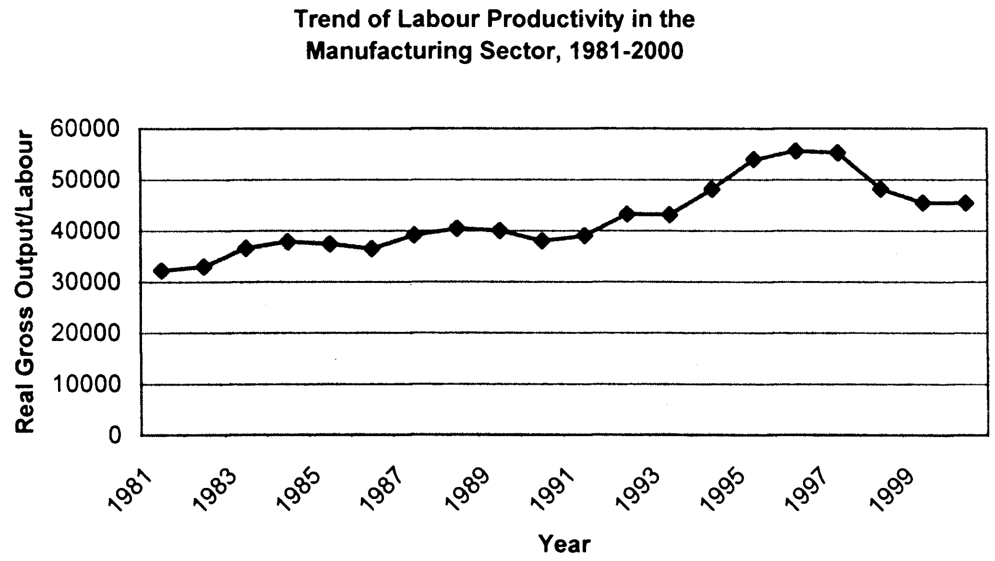


Figure 2.2

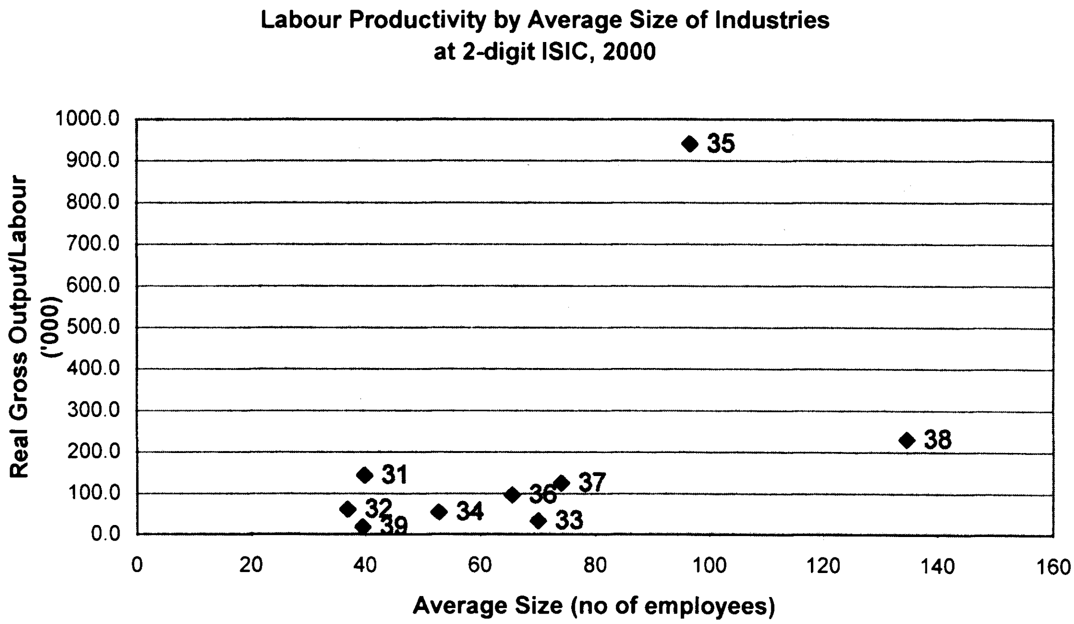


Figure 2.3

Table 2.4 :
Determinants of Industry Performance

Variables	Level	First Difference
Constant	1.7762 (0.3298)	-0.0187 (0.0112)
k	0.1243 (0.0149) **	0.2819 (0.0206) **
m	0.2348 (0.0208) **	0.5024 (0.0235) **
D	-0.0601 (0.0149) **	0.0038 (0.0100)
s	0.2313 (0.0162) **	0.1748 (0.0160) **
x	-0.0345 (0.0121) **	-0.0271 (0.0127) *
$(n+g+\delta)$	-0.0694 (0.0171) **	-0.0835 (0.0096) **
R^2 : within between overall	0.6220 0.7488 0.7504	0.6236 0.3803 0.6074
F-stat (P value)	216.23 (0.000)	193.82 (0.000)
Ramsey test	36.04 (0.000)	15.28 (0.000)
VIF	1.99	1.26
Observations	999	892

Notes:
*(1) Coefficients are labelled ** to denote statistical significance at 1%.*
(2) Values in parentheses are standard errors, except for F- stat test.
Source: Generated from UNIDO database.

Table 2.5 :
Dependent Variable: Labour Productivity by Average Size, 1981-1999
(Size Indicator: Average Gross Output as a Proxy to Annual Sales Turnover)

Variables	Level				First Difference			
	Total	Small Ind.	Medium Ind.	Large Ind.	Total	Small Ind.	Medium Ind.	Large Ind.
Constant	1.7762	4.4287	0.8655	0.4704	-0.0187	-0.0083	0.0043	-0.0594
	(0.3298)	(0.7307)	(0.6935)	(0.6248)	(0.0112)	(0.0168)	(0.0200)	(0.0210)
k	0.1243	0.0808	0.1322	0.1424	0.2819	0.3989	0.1156	0.3546
	(0.0149) **	(0.0333) *	(0.0208) **	(0.0346)**	(0.0206) **	(0.0336)**	(0.0295) **	(0.0411) **
m	0.2348	0.1254	0.2857	0.3231	0.5024	0.4865	0.4438	0.5836
	(0.0208) **	(0.0384) **	(0.0352) **	(0.0339) **	(0.0235) **	(0.0373) **	(0.0427) **	(0.0412) **
D	-0.0601	-0.0287	-0.0620	-0.0829	0.0038	0.0035	0.0063	-0.0246
	(0.0149) **	(0.0251)	(0.0204) **	(0.0259) **	(0.0100)	(0.0152)	(0.0155)	(0.0179)
s	0.2313	0.1953	0.2271	0.1895	0.1748	0.0870	0.1031	0.2405
	(0.0162) **	(0.0336) **	(0.0410) **	(0.0427) **	(0.0160) **	(0.0234) **	(0.0318) **	(0.0284) **
x	-0.0345	-0.0447	-0.0467	0.0149	-0.0271	-0.0667	-0.0200	0.0168
	(0.0121) **	(0.0236)	(0.0206) *	(0.0188)	(0.0127) *	(0.0204) **	(0.0261)	(0.0174)
$(n+g+\delta)$	-0.0694	-0.0599	-0.3194	-0.0420	-0.0835	-0.0455	-0.2687	-0.0619
	(0.0171) **	(0.0208) **	(0.0434) **	(0.0414)	(0.0096) **	(0.0115) **	(0.0215) **	(0.0216)**
R^2 : within	0.6220	0.4405	0.6774	0.5753	0.6236	0.6066	0.5935	0.7867
between	0.7488	0.4697	0.4512	0.4053	0.3803	0.8268	0.2936	0.6810
overall	0.7504	0.4254	0.3639	0.5180	0.6074	0.6261	0.5392	0.7687
F-stat (P value)	216.23	34.41	81.27	54.38	193.82	56.17	50.89	138.57
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ramsey test	36.04	0.58	5.03	14.66	15.28	3.19	54.62	11.35
	(0.000)	(0.630)	(0.002)	(0.000)	(0.000)	(0.023)	(0.000)	(0.000)
VIF	1.99	1.98	1.64	1.68	1.26	1.43	1.51	1.50
Observations	999	356	325	318	892	302	291	299

*Notes: (1) Coefficients are labelled ** and * to denote statistical significance at 1% and 5%, respectively.*
(2) Values in parentheses are standard errors except for F-stat and Ramsey tests .
Source: Generated from UNIDO database.

Table 2.6 :
Dependent Variable: Labour Productivity by Relative Size, 1981-1999
(Size Indicator: Average Number of Employment)

Variables	Level				First Difference			
	Total	Small Ind.	Medium Ind.	Large Ind.	Total	Small Ind.	Medium Ind.	Large Ind.
Constant	1.8597	2.3940	2.1054	1.7742	0.0049	-0.0081	0.0189	-0.0631
	(0.3614)	(0.5360)	(0.6558)	(0.8333)	(0.0119)	(0.0182)	(0.0186)	(0.0265)
k	0.1562	0.1103	0.0972	0.2749	0.3106	0.4277	0.2176	0.1065
	(0.0161) **	(0.0261) **	(0.0275) **	(0.0469) **	(0.0216) **	(0.0317) **	(0.0365) **	(0.0418) *
m	0.4074	0.3922	0.4135	0.3700	0.6259	0.5607	0.7004	0.6774
	(0.0203) **	(0.0291) **	(0.0367) **	(0.0414) **	(0.0220) **	(0.0353) **	(0.0380) **	(0.0398)**
D	-0.0888	-0.0260	-0.0642	-0.1049	0.0206	0.0142	0.0027	0.0468
	(0.0161) **	(0.0201)	(0.0224) **	(0.0373) **	(0.0106)	(0.0149)	(0.0174)	(0.0199) *
s	-0.0790	-0.0680	-0.0755	-0.2145	-0.0753	-0.0272	-0.1544	-0.0981
	(0.0195) **	(0.0319) *	(0.0661)	(0.0677) **	(0.0180) **	(0.0230)	(0.0397) **	(0.0415) *
x	-0.0031	-0.0165	0.0273	0.0460	-0.0168	-0.0531	0.0093	0.0482
	(0.0134)	(0.0198)	(0.0249)	(0.0299)	(0.0135)	(0.0204) **	(0.0227)	(0.0244) *
$(n+g+\delta)$	-0.0551	-0.0436	0.0239	-0.0800	-0.0892	-0.0470	-0.1200	-0.2546
	(0.0188) **	(0.0163) **	(0.0568)	(0.0603)	(0.0102) **	(0.0109) **	(0.0238) **	(0.0272) **
R^2 : within	0.5471	0.6920	0.6135	0.4391	0.5782	0.6516	0.6570	0.6257
between	0.5327	0.4576	0.4597	0.5796	0.2733	0.8141	0.4424	0.3578
overall	0.5024	0.4244	0.4893	0.5606	0.5616	0.6433	0.6386	0.5622
F-stat (P value)	158.75	94.67	65.09	28.63	160.36	67.59	71.97	55.64
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ramsey test	58.59 (0.000)	22.18 (0.000)	19.19 (0.000)	41.95 (0.000)	38.80 (0.000)	83.90 (0.000)	23.02 (0.000)	8.27 (0.000)
VIF	1.70	1.80	1.84	1.68	1.15	1.20	1.15	1.29
Observations	999	352	345	302	892	302	315	275

*Notes: (1) Coefficients are labelled ** and * to denote statistical significance at 1% and 5%, respectively.*
(2) Values in parentheses are standard errors except for F-stat and Ramsey tests.
Source: Generated from UNIDO database.

Table 2.7 :
Dependent Variable: Labour Productivity by Average Size, 1981-1999
(Size Indicator: Average Capital Stock as a Proxy to Paid-up Capital)

Variables	Level: Total	Level: Small Ind.	Level: Medium Ind.	Level: Large Ind.	First Difference: Total	First Difference: Small Ind.	First Difference: Medium Ind.	First Difference: Large Ind.
Constant	1.8597 (0.3614)	1.3061 (0.5689)	-1.6618 (0.8369)	-.3216 (0.9882)	0.0049 (0.0119)	0.0139 (0.0129)	0.0380 (0.0226)	-0.0332 (0.0307)
k	0.2353 (0.0250) **	0.2156 (0.0345) **	0.4612 (0.0464) **	0.3238 (0.0628) **	.3860 (0.0268) **	0.5919 (0.0434) **	0.3226 (0.0389) **	0.4328 (0.0643)**
m	0.4074 (0.0203) **	0.4627 (0.0316) **	0.4656 (0.0341) **	0.4460 (0.0396) **	0.6259 (0.0220) **	0.6315 (0.0282) **	0.5087 (0.0363) **	0.7433 (0.0446) **
D	-0.0888 (0.0161) **	-0.0806 (0.0185) **	-0.0457 (0.0174) **	-0.1385 (0.0402) **	0.0206 (0.0106)	0.0078 (0.0112)	-0.0065 (0.0159)	0.0348 (0.0268)
s	-0.0790 (0.0195) **	-0.0625 (0.0229) **	-0.0903 (0.0431) *	-0.0747 (0.0575)	-0.0753 (0.0180) **	-0.0428 (0.0173) *	-0.1244 (0.0321) **	-0.1510 (0.0468) **
x	-0.0031 (0.0134)	-0.0859 (0.0234) **	0.0182 (0.0178)	0.0904 (0.0276) **	-0.0168 (0.0135)	-0.0435 (0.0206) *	-0.0494 (0.0250) *	0.0178 (0.0232)
$(n+g+\delta)$	-0.0551 (0.0188) **	-0.1113 (0.0362) **	-0.0153 (0.0144)	-0.0567 (0.0542)	-0.0892 (0.0102) **	-0.1096 (0.0197) **	-0.0397 (0.0113) **	-0.1281 (0.0268) **
R^2 : within	0.5471	0.6663	0.6839	0.4922	0.5782	0.7795	0.5849	0.5739
between	0.5327	0.4146	0.5550	0.6011	0.2733	0.5339	0.6057	0.2984
overall	0.5024	0.3993	0.5730	0.6194	0.5616	0.7491	0.5712	0.5546
F-stat (P value)	158.75 (0.000)	92.71 (0.000)	82.85 (0.000)	37.81 (0.000)	160.36 (0.000)	142.41 (0.000)	48.51 (0.000)	47.71 (0.000)
Ramsey test	58.59 (0.000)	16.10 (0.000)	2.12 (0.0976)	20.79 (0.000)	38.80 (0.000)	3.19 (0.0239)	54.62 (0.000)	11.35 (0.000)
VIF	2.51	2.41	1.75	1.99	1.35	1.43	1.51	1.50
Observations	999	371	318	310	892	325	287	280

Notes:
*(1) Coefficients are labelled ** and * to denote statistical significance at 1% and 5%, respectively.*
(2) Values in parentheses are standard errors except for F-stat and Ramsey tests.
Source: Generated from UNIDO database.

Table 2.8 :
Dependent Variable: Labour Productivity and Labour Productivity Growth by Different Periods, 1981-1999

Variables	Level				First Difference			
	1981-1985 (1)	1986-1990 (2)	1991-1995 (3)	1996-1999 (4)	1981-1985 (5)	1986-1990 (6)	1991-1995 (7)	1996-1999 (8)
Constant	-7.7500	2.6719	0.3793	-9.413	-0.0380	-0.0000	-0.0421	-0.0615
	(0.8334)	(0.5496)	(0.5773)	(1.0617)	(0.0093)	(0.0115)	(0.0108)	(0.0064)
k	0.4898	0.0770	0.0338	0.6108	0.7365	0.0957	0.4699	0.7784
	(0.0449) **	(0.0253) **	(0.0295)	(0.0592)**	(0.0682) **	(0.0313) **	(0.0518) **	(0.0420) **
m	0.5910	-0.0063	0.5524	-0.0652	0.6978	-0.0253	0.6236	0.7432
	(0.0419) **	(0.0532)	(0.0312) **	(0.0376)	(0.0444) **	(0.0645)	(0.0508) **	(0.0531) **
D	-0.0133	-0.0331	-0.0190	-0.0053	-0.0155	0.0091	-0.0636	-0.0069
	(0.0115)	(0.0230)	(0.0180)	(0.0130)	(0.0146)	(0.0268)	(0.0201) **	(0.0108)
s	0.2217	0.5189	0.0168	0.9981	0.1495	0.6097	0.0668	-0.0232
	(0.0283) **	(0.0478) **	(0.0202)	(0.0299) **	(0.0290) **	(0.0576) **	(0.0201) **	(0.0435)
x	-0.0773	-0.0591	-0.0710	0.0039	-0.0073	-0.0459	-0.0079	0.0005
	(0.0168) **	(0.0199) **	(0.0237)**	(0.0276)	(0.0209)	(0.0234)	(0.0272)	(0.0196)
$(n+g+\delta)$	-0.0854	-0.0273	-0.3735	-0.1470	-0.0248	-0.0834	-0.0571	-0.0379
	(0.0254) **	(0.0119) *	(0.0342)**	(0.0470) **	(0.0341)	(0.0139) **	(0.0250) *	(0.0212)
R^2 : within	0.8416	0.6609	0.7830	0.9097	0.8870	0.5878	0.6375	0.8864
between	0.7397	0.7174	0.2751	0.6205	0.8751	0.4201	0.5418	0.2683
overall	0.7327	0.7244	0.2896	0.6529	0.8804	0.5499	0.5613	0.7849
F-stat (P value)	145.24	66.60	148.42	248.60	134.81	22.54	56.87	187.33
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Ramsey test	53.62	28.73	9.97	12.88	14.04	4.11	15.74	11.25
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.007)	(0.000)	(0.000)
VIF	1.36	1.48	1.98	1.64	1.40	1.15	1.15	1.28
Observations	234	271	270	224	168	262	256	206

*Notes: (1) Coefficients are labelled ** and * to denote statistical significance at 1% and 5%, respectively.*
(2) Values in parentheses are standard error except for F-stat and Ramsey tests.
Source: Generated from UNIDO database

Table 2.9 :
Dependent Variable: Labour Productivity and Labour Productivity Growth with Industries at 2-digit and 3-digit Levels Dummies, 1981-1999

Variables		Level		First Difference	
		(1)	(2)	(3)	(4)
Constant		1.4411 (0.3204)	1.5343 (0.3012)	-0.0407 (0.0294)	-0.0408 0.0293)
k		0.1435 (0.0130) **	0.1402 (0.0129) **	0.2867 (0.0197) **	0.2891 (0.0196) **
m		0.2333 (0.0173) **	0.2369 (0.0170) **	0.4893 (0.0227) **	0.4893 (0.0226) **
D		-0.0586 (0.0149) **	-0.0598 (0.0148) **	0.0030 (0.0096)	0.0031 (0.0095)
s		0.2368 (0.0143) **	0.2286 (0.0142) **	0.1789 (0.0151) **	0.1798 (0.0151) **
x		-0.0332 (0.0104) **	-0.0343 (0.0103) **	-0.0252 (0.0120) *	-0.0241 (0.0119) *
$(n+g+\delta)$		-0.0660 (0.0171) **	-0.0660 (0.0171) **	-0.0777 (0.0090) **	-0.0772 (0.0090) **
D31		0.2723 (0.2401)	0.2820 (0.2090) **	0.0330 (0.0301)	0.0329 (0.0299)
D32		-0.0675 (0.2502)	-0.0679 (0.2174) **	0.0146 (0.0317)	0.0143 (0.0316)
D33		-0.3454 (0.2851)		0.0262 (0.0333)	
	D331		-0.3877 (0.2642)		0.0497 (0.0347)
	D332		-0.2252 (0.3708)		-0.0333 (0.0419)
D34		-0.1004 (0.2854)	-0.0948 (0.2477)	-0.0259 (0.0327)	-0.0265 (0.0326)
D35		0.4034 (0.2458)		0.0041 (0.0305)	
	D351		0.7492 (0.2672) **		0.0204 (0.0336)
	D352		0.4324 (0.2474)		0.0111 (0.0322)
	D353		1.6118 (0.3762) **		-0.0549 (0.0399)
	D355		-0.2510 (0.2956)		0.0069 (0.0350)
	D356		-0.4797 (0.3706)		-0.0165 (0.0399)
D36		-0.1041 (0.2733)	-0.0942 (0.2374)	0.0140 (0.0319)	0.0137 (0.0318)
D37		0.2364 (0.3415)	0.2538 (0.2966)	0.0205 (0.0372)	0.0203 (0.0370)
D38		-0.0452 (0.2333)	-0.0364 (0.2030)	-0.0028 (0.0305)	-0.0032 (0.0304)
R^2 :	**within**	0.6210	0.6213	0.6228	0.6228
	between	0.8020	0.8686	0.4765	0.5311
	overall	0.7928	0.8580	0.6154	0.6206
Wald χ^2 **(P value)**		1788.47 (0.000)	1928.93 (0.000)	1403.26 (0.000)	1426.37 (0.000)
Ramsey Test		91.92 (0.000)	42.95 (0.000)	33.90 (0.000)	32.44 (0.000)
VIF		4.45	3.88	4.52	3.70
Observations		999	999	892	892

*Notes: (1) Coefficients are labelled ** and * to denote statistical significance at 1% and 5%, respectively.*
(2) Values in parentheses are standard errors, except for p-value for Wald chi-sq except and Ramsey tests
Source: Generated from UNIDO database.

Appendix 2.I

Description of Variables

Real gross output and capital are calculated into constant prices using the GDP deflator (1987 as base year for Malaysia), in the absence of a sector-level producer price index to give real output, Y. The value of census output covers only activities of an industrial nature and is compiled on a production basis. This is comprised of the value of all products of the establishments; the net change between the beginning and the end of the reference period in the value of work in progress and stocks of goods to be shipped in the same condition as received; the value of industrial work done or industrial services rendered to others; the value of goods shipped in the same condition as received less the amount paid for these goods; and the value of fixed assets produced during the period by the unit for its own use. Valuation is in factor cost, excluding all indirect taxes falling on production and including all current subsidies received in support of production activity.

Bought-in materials and services are calculated from output minus value added, i.e. $M = Y - VA$. Bought-in materials is the value of materials consumed in production (including transport charges incurred, and taxes and duties paid on materials); while bought-in services is the value of supplies consumed such as packaging materials, consumable stores (including stationery and office supplies, materials for repairs and maintenance), cost of printing, lubricants, cost of goods sold in same condition as purchases, water, electricity, fuel, payments to contractors, payments for industrial work done by others, supplies and payments for non-industrial services.

Either value added per employee and gross output per employee can be used as proxies for labour productivity (National Productivity Corporation, 2002). Gross output based labour productivity measures are more sensitive to the degree of vertical integration and outsourcing than value-added based labour productivity measures (OECD, 2001). On the other hand, value added based labour productivity produce negative values in the event of losses. Due to that, the former definition is preferred to overcome the problem of non-positive labour productivity and therefore avoid losses of observations when transformed to log. To obtain labour productivity, Y^*, gross real output is divided with the number of full time employees. Since data on industrial working hours is not available, employment is measured by the number of workers employed in the industries. Employment is defined as the number of persons who worked in or for the establishments during the reference year, excluding home workers. The concept covers working proprietors, active business partners and unpaid family workers as well as employees. The figures reported normally refer to the average number of persons engaged during the reference year, obtained as the sum of the 'average number of employees' during the year and the total number of other persons engaged measured for a single period of the year.

Due to the absence of capital stock data, I construct physical capital stock from gross fixed capital formation, deflated over time using the gross domestic product deflator (1987 – base year), using the perpetual inventory method, as follows,

$$K_t = (1-\delta)K_{t-1} + I_t$$

where K_t represents the current capital stock, δ is the rate of physical capital depreciation, K_{t-1} is the capital stock in the previous year and I_t is investment, which is given by real gross fixed capital formation. We estimate an initial value of the 1980 capital stock for each industry as $K_{1980} = \frac{I_{1981}}{(g+\delta)}$, where g is calculated as the average geometric growth rate from 1981 to 1999, under the assumption that over long periods of time, capital and output grow at the same rate. A depreciation rate of 6% is assumed[13]. For the rest of the chapter, I use K to denote capital-labour ratio.

Economic performance, D, is derived from the industrial production index growth (IPIG) of industries at three-digit level. IPIG at four-digit level is not available. A dummy variable is then generated to capture non-positive growth for these industries. Initially, two dummies are tested, (i) to include 0% growth, and (ii) to exclude 0% growth, from the dummy variable. The dummy that includes the 0% growth is found to generate significance for all variables at 5% confidence interval. Therefore, the model includes 0% IPIG for the economic performance dummy variable.

Exports, X, is real total industrial exports to the world, valued at freight on board (f.o.b.) prices, deflated over time using the gross domestic product deflator (1987 – base year). Within the $(n+g+\delta)$ component of the model, n represents the rate of labour growth and is allowed to change with time, g is the growth of industries and is assumed to be constant, and δ is the depreciation rate of physical capital stock. MRW model measures n as the average rate of growth of the working population, where working age is defined as 15-64 years, this model measures n as the rate of employment within each of the four-digit level industries. $(g+\delta)$, collectively, is constant and assumed to be at 0.07. Variable $(n+g+\delta)$ is not transformed into log due to significantly high occurrences of negative value. Transforming this variable into log would mean a loss of more than 400 observations. Therefore, this variable will maintain its actual level value in the semilog model.

[13] Following the assumption of Hall and Jones (1999).

Appendix 2.II

Measures of Average Sizes

(1) Average size of industries is defined by the average number of workers per establishment. This is one of the common methods of identifying the size of firms, besides their paid-up capital and turnover of sales. From this value, percentiles of the first 40% represent the small size industries, the second 30% represents the medium industries whereas the third 30% represents the large industries. The first percentile consists of industries with an average number of workers per establishment of less than 62, the second, from 62 workers to less than 109, and the third, equal to and more than 110 workers. Of course, the definition of relative sizes of industries or firms may vary, depending on the government authority[14]. Percentiles, in this case, are used for convenience, particularly to distribute the number of observations quite evenly among the grouped samples.

(2) Size can also be characterised by annual sales turnover. Average gross output of each establishment within each industry is used as a proxy for annual sales turnover. Average gross output or production represents the value of goods and/or services produced in a year whether sold or stocked. The related measure, annual sales turnover, corresponds to the actual sales in the year and can be greater than production in a given year if all production is sold together with stock from the previous years. While production and turnover will be different in a year, their averages over a long period of time should converge. This would depend on how perishable the stock is. As in this case, gross output of the industry is divided by the number of establishments within the industry. The small industries consist of industries with average real annual sales turnover less than US$1,800,000, the medium industries, from US$1,800,000 to less than US$5,340,000, and the large industries, equal to and more than US$5,340,000.

[14] The State Government, Ministry of International Trade and Industries (MITI) (see Appendix 4) and the Department of Statistics use different definitions in identifying the size of firms.

(3) Paid-up capital is another definition that may be used to categorise the sizes of manufacturing establishments. In this study, capital stock is used as a proxy for paid-up capital. The small industries consist of industries with average real paid-up capital of less than U$1,550,000, the medium industries, between U$1,550,000 to less than U$5,000,000, and the large industries, equal to and more than U$5,000,000.

Appendix 2.III

Definitions of Small, Medium and Large Enterprises

Various definitions have been given to small and medium enterprises (SMEs) within Malaysia and among different countries. World Bank (1984), United Nations Development Organisation (1986) and Asia Development Bank (1990) have defined small and medium enterprises as follows[15]:

1. small-sized firms employ less than 50 workers
2. medium-sized firms employ between 50 and 199 workers.

From this definition, the large entreprises are presumed to be establishments employing 200 and more employees.

The Small and Medium Industries Development Corporation (SMIDEC, 1995) defined SMEs as manufacturing establishments that have annual sales turnover not exceeding RM25 million[16] and full-time employees not exceeding 150. A manufacturing establishment that has a paid-up capital of less than RM500,000[17] and employees not exceeding 50 is considered as small, whereas one that has a

[15] Aba-Ibrahim (2003).
[16] Equivalent to US$6.58 million based on Malaysia's pegged exchange rate to the US$, RM3.80/1US$.
[17] Equivalent to US$131,579.

paid-up capital of RM500,001 to RM2.5 million and employs between 51 and 150 full-time employees is considered as medium-sized.

More recently, the Ministry of International Trade and Industry (MITI) has reclassified the sizes of enterprises[18] as,

1. Small enterprises are manufacturing enterprises that employ less than or equal to 50 full-time employees, and with an annual turnover of not more than RM10 million[19],
2. Medium enterprises are manufacturing enterprises that employ between 51 to 150 employees, and with an annual turnover of between RM10 million to RM25 million[20].
3. Large enterprises are manufacturing enterprises that employ more than 150 employees, and with an annual turnover of more than RM25 million.

MITI widened this classification of SMIs to allow for more establishments to benefit from their incentives and funds. Furthermore, by including the turnover sales can sometimes reflect more of the establishments' size rather than the number of full-time employees they employ or the paid-up capital that they have invested into the business.

[18] Incentives and funds allocated by the Federal Government are based on this classification.
[19] RM10 million = US$2.63 million (small enterprises).
[20] Ibid.

Appendix 2.IV

List of Industries at 4-digit level

ISIC	Industries
3111	Slaughtering, preparing and preserving meat
3112	Manufacture of dairy products
3113	Canning and preserving of fruits and vegetables
3114	Canning, preserving and processing of fish, crustacea and similar foods
3115	Manufacture of vegetable and animal oils and fats
3116	Grain mill products
3117	Manufacture of bakery products
3118	Sugar factories and refineries
3119	Manufacture of cocoa, chocolate and sugar confectionery
3121	Manufacture of food products not elsewhere classified
3122	Manufacture of prepared animal feeds
3131	Distilling, rectifying and blending spirits
3134	Soft drinks and carbonated waters industries
3140	Tobacco manufactures
3211	Spinning, weaving and finishing textiles
3212	Manufacture of made-up textile goods except wearing apparel
3213	Knitting mills
3214	Manufacture of carpets and rugs
3215	Cordage, rope and twine industries
3220	Manufacture of wearing apparel, except footwear
3231	Tanneries and leather finishing
3233	Manufacture of products of leather and leather substitutes, except footwear and wearing apparel
3240	Manufacture of footwear, except vulcanized or moulded rubber or plastic footwear
3311	Sawmills, planing and other wood mills
3312	Manufacture of wooden and cane containers and small cane ware
3319	Manufacture of wood and cork products not elsewhere classified
3320	Manufacture of furniture and fixtures, except primarily of metal
3411	Manufacture of pulp, paper and paperboard
3412	Manufacture of containers and boxes of paper and paperboard
3419	Manufacture of pulp, paper and paperboard articles n.e.c.
3420	Printing, publishing and allied industries
3511	Manufacture of basic industrial chemicals except fertilizers
3512	Manufacture of fertilizers and pesticides
3513	Manufacture of synthetic resins, plastic materials and man-made fibres except glass
3521	Manufacture of paints, varnishes and lacquers
3522	Manufacture of drugs and medicines
3523	Manufacture of soap and cleaning preparations, perfumes, cosmetics and other toilet preparations

3529	Manufacture of chemical products not elsewhere classified
3530	Petroleum refineries
3540	Manufacture of miscellaneous products of petroleum and coal
3551	Tyre and tube industries
3559	Manufacture of rubber products not elsewhere classified
3560	Manufacture of plastic products not elsewhere classified
3610	Manufacture of pottery, china and earthenware
3620	Manufacture of glass and glass products
3691	Manufacture of structural clay products
3692	Manufacture of cement, lime and plaster
3699	Manufacture of non-metallic mineral products n.e.c.
3710	Iron and steel basic industries
3720	Non-ferrous metal basic industries
3811	Manufacture of cutlery, hand tools and general hardware
3812	Manufacture of furniture and fixtures primarily of metal
3813	Manufacture of structural metal products
3819	Manufacture of fabricated metal products except machinery and equipment not elsewhere classified
3821	Manufacture of engines and turbines
3823	Manufacture of metal and wood working machinery
3824	Manufacture of special industrial machinery and equipment except metal and wood working machinery
3825	Manufacture of office, computing and accounting machinery
3829	Machinery and equipment except electrical n.e.c.
3831	Manufacture of electrical industrial machinery and apparatus
3832	Manufacture of radio, television and communication equipment and apparatus
3833	Manufacture of electrical appliances and housewares
3839	Manufacture of electrical apparatus and supplies n.e.c.
3841	Ship building and repairing
3842	Manufacture of railroad equipment
3843	Manufacture of motor vehicles
3844	Manufacture of motorcycles and bicycles
3851	Manufacture of professional and scientific, and measuring and controlling equipment, n.e.c.
3852	Manufacture of photographic and optical goods
3853	Manufacture of watches and clocks
3901	Manufacture of jewellery and related articles
3902	Manufacture of musical instruments
3909	Manufacturing industries not elsewhere classified

Appendix 2.V

List of Industries at 2-digit and 3-digit Level

No.	ISICode	Industries[1]
1.	31	Food and Beverages
2.	32	Textiles and Apparel
3.	331	Wood Products
4.	332	Furniture
5.	34	Paper and Printing
6.	351	Industrial Chemicals
7.	352	Other Chemicals
8.	353	Petroleum Refineries
9.	354	Miscellaneous Petroleum
10.	355	Rubber
11.	356	Plastic
12.	36	Non-metallic Minerals Product
13.	37	Iron and Steel
14.	38	Fabricated Metal and Machinery

Notes : [1] *ISIC 390 industry is omitted from this list, due to very low contribution to total output and to avoid dummy variable trap.*

LONG RUN RELATIONSHIP BETWEEN R&D AND PRODUCTIVITY

This study examines whether research and development has a long run relationship with total factor productivity of the manufacturing industries in the UK. R&D are decomposed into R&D capital by (1) the industry own enterprises, (2) other industries enterprises, and (3) foreign R&D capital. Panel unit root and panel cointegration tests are performed on a panel of 20 industries during 1980-2002. Panel unit root tests generally show that all variables are integrated of order one, except for foreign R&D. Kao (1999) and Pedroni (1999) residual-based panel cointegration tests show that whether I include the foreign R&D capital or not in the regressions does not significantly change the predictions from both these tests. I find R&D and productivity to be cointegrated in the long run. Further, the elasticities of productivity with respect to these R&D variables are measured. I find the industries benefit from other domestic industries and foreign R&D but not their own.

JEL Classification: D24, L60, O3, C33
Keywords: Total Factor Productivity, Research and Development, Panel Cointegration, Spillovers.

3.1 Introduction

This chapter examines whether R&D has a long run relationship with total factor productivity (TFP). As the literature mainly use macro data and firm level data, I explore the industry level data to see if it confirms the earlier findings made from macro and firm level data. In addition to a country's own R&D and foreign R&D in the macro data model, I use the industry R&D and other domestic industrial R&D to obtain the information on how far an industry R&D capital influence its productivity and how far it benefits from R&D spillovers from other industries. It is the objective of this study to identify whether R&D accumulated expenditure and TFP are significantly related in the long run. The R&D expenditure of other industries within the sector and those from foreign countries are also analysed as a way to establish a spillover effect from other industries within the economy and other economies. My results provide evidence that the manufacturing industries in the UK benefit from other domestic industries R&D and foreign R&D spillovers but not their own R&D activities.

Commercially-oriented innovation efforts are the major engine of technological progress and productivity growth (see Coe and Helpman (1995) and Romer (1990)). Further, Griliches (1988) and Coe and Moghadan (1993) provide convincing empirical evidence that cumulative domestic R&D is an important determinant of productivity. A country's own R&D brings about more effective use of existing resources and thereby raises its productivity level. Apart from this, in an open economy, a country's productivity depends on the R&D efforts of its trading partners as well as on its own R&D. The R&D efforts of its trading partners are transmitted mainly through international trade and foreign direct investment. Foreign acquisition, for instance, offers the opportunity for the inward transfer of technology and firm-specific capabilities (Girma et al, 2006). Following acquisition, the foreign owned companies on average, are found to improve their productivity and outperform the domestic firms (Conyon et al, 2002). From these ventures, the country benefit from technical advances, either directly or indirectly. Direct benefits can be in the form of learning new technologies, production processes and organisational methods. Indirect benefits emanate from the developed goods and services imported from their trading partners.

In this chapter, I study on the extent to which an industry's productivity level depends on its R&D and those from others. I discover a puzzling result that whereas the total domestic R&D has a significant positive effect on the industries productivity, the industry's own R&D does not. In explaining the effect of other industries on the productivity of an industry, Bernstein (1989) points out that R&D capital accumulation in one industry can affect the production cost of firms operating in other industries. He finds that R&D spillovers enable firms to reduce cost of production and thereby profit from other firms' R&D activities.

In this study, I contribute to the existing literature by providing an insight into the possible economic reason for the UK industry R&D results that contradicts country level findings. Unlike the positive impact of domestic R&D on TFP at country level, the industry R&D has a negative impact on its TFP. This result proves the industry does not rely on its own R&D to improve its productivity but rather the collective R&D efforts of all industries in the economy. Even though the industry's R&D is a cost to the industry, it is still crucial for each industry to perform their R&D due to its social returns. Due to its public good nature, other industries seem to be benefiting collectively from the R&D efforts of domestic industries within the economy. This makes it important for every industry to pursue their R&D efforts even though it has a negative impact on its own industry.

3.2 Brief Literature Review

Much research has been carried out in recent decades to assess the influence of research and development on productivity. There is now a large body of literature that provides theoretical as well as empirical models where cumulative R&D is an important source of technological change and productivity growth. Griliches (1995) notes that, both public investment in science and private investments in industrial R&D have been crucial contributors to world economic growth in the past and they are likely to continue in the future.

Coe and Helpman (1995) seminal contribution provides empirical evidence on the effect of accumulated spending on R&D by a country and its trading partners on its total factor productivity (TFP). Using a panel of 21 OECD countries and Israel over the period of 1971-1990, they find the domestic R&D capital stock affects the domestic TFP more than the foreign R&D capital stocks. However, smaller countries are more likely to benefit from foreign R&D capital than their own R&D capital stock. Frantzen (2003) analyses the long run relationship between domestic and foreign R&D spillover and productivity for a panel of 14 OECD countries during the period 1972-94. He finds the three variables to have a long run relationship and the causation to run from the R&D variables to productivity rather than the other way around. Bronzini & Piselli (2005) identify long-run relationships between TFP and R&D capital stock, human capital and public capital in Italian regions for the period of 1980-2001. They find evidence of a long-run relationship between them. In their Granger-causality tests, R&D capital stock is found to have a bi-directional causality, whereas human and public capitals cause productivity growth but not the other way around. Anon Higon (2004) analyses the impact of R&D spillovers on 8 UK manufacturing industries for the period 1970-1997. Using Pesaran et al (1999) pool mean group estimator and Pedroni (1999) cointegration tests, she finds the domestic R&D has a significant positive impact on the industry's productivity whereas foreign R&D is not significant. Anon Higon (2004) concluded that foreign R&D and UK industrial productivity do not have a long run relationship.

Earlier works on R&D have been mainly US-based, for example those contributed by Minasian (1969), Griliches (1980, 1986), Mansfield (1980), Schankerman (1981), and Griliches and Mairesse (1984), among others. Griliches and Mairesse (1984), for instance, uses a production function framework to analyse the impact of past cumulated R&D expenditures on the output (deflated sales) of over a hundred large US firms, covering a twelve-year time period (1966-77). They find there is a strong relationship between firm productivity and the level of its past R&D investments in the cross-sectional dimension, but that in the within-firm time-series dimension of the data, this relationship almost vanishes. Griliches and Lichtenberg (1984) examine the relationship between R&D and productivity growth in US manufacturing industries at 2 and 3 Standardised Industrial Classification (SIC) levels. While there has been an overall decline in productivity growth, including in R&D intensive industries, the statistical relationship between productivity growth and R&D intensity did not disappear. Mansfield (1984) reviews a wide-ranging research program on R&D, innovation and technological change. One of the studies at industry level that he reviewed indicates that the relationship of productivity and R&D improves as longer time period are covered.

Earlier studies on the UK include Sterlachinni (1989) who perform cross-sectional study on 15 British manufacturing industries on TFP, R&D and innovations for 1954-1984 time periods. He finds that the productivity slowdown over 1973-79 in British manufacturing is significantly associated with a declining propensity to perform R&D activities. Englander et al (1988) explain that it is possible that the slowdown in the growth of TFP is due to the slowing down of the generation and diffusion of new technology, given there was a long-run role of technological change. Griliches (1979) argues, to generate productivity growth, R&D expenditures should be raised, taking into account the time lag. Sterlachini (1989) points out that lags structure in analysing the effects of R&D on TFP growth is important. When measuring the returns of R&D, time is a critical variable. Their innovation history appears to be important in influencing the rate of return to R&D. In a later study by Wakelin (2001) on 170 UK manufacturing firms, a static panel data model is used to analyse the impact of R&D expenditure to labour productivity growth. The firm's own R&D expenditure is found to have a significant positive effect on productivity growth.

The studies in this literature can be grouped into 2 types of data, namely (1) macro data that normally compares between countries, (2) micro data that use industry data or firm level data. In macro data studies, there is a tendency to include international R&D spillover effects besides the country own R&D. This is to avoid from overstating own-country R&D contribution to country-level productivity growth. In this case, excluding the spillover effects from other countries will cause the own-country-specific rates of return to R&D to be overstated and global R&D on the country returns will be understated (Alston and Pardey, 2001). Due to this reason, this literature mainly focuses on the macro data by aggregating the country specific research investments into knowledge stocks. This is unavoidable in an attempt to capture interstate or intercountry spillover effects in their econometric models. Even though most of the literature finds evidence that there is significant international spillover effects among OECD countries, Anon Higon (2004) in her UK manufacturing industries study finds that, R&D externalities in the UK manufacturing sector are primarily an intranational phenomenon.

Firm level studies, on the other hand, may face a selection bias problem. Firms may be selected out of convenience or based on their favourable performance in R&D, disregarding the characteristics of other firms that are excluded in their sample. This problem is aggravated when the proportion of the sample are small compared to the population of the whole industry. The results may not be representative to the population, even though R&D expenditure made by these enterprises represents a high percentage of the total R&D expenditure made by the total industry.

3.3 Empirical Framework and Methodology

This study adopts a Cobb-Douglas production function extended with intermediate materials, as follows:

$$Q_{it} = A_{it} K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M} \qquad (3.1)$$

where

Q_{it} - real gross output of industry i at time t

A_{it} - technological progress

K_{it} - physical capital stock

L_{it} - labour input

M_{it} - intermediate materials

From equation (3.1), the technological progress, which is derived as a Solow residual, *A,* is assumed to be Hicks-neutral[1] and disembodied. This means technical change raises the maximum output that can be produced with a given level of inputs without changing the relationship between them. Next, I divide both sides of equation (3.1) by $K_{it}^{\beta_K}$, $L_{it}^{\beta_L}$ and $M_{it}^{\beta_M}$, so that the left-hand side of the equation becomes the TFP, as follows:

$$\frac{Q_{it}}{K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M}} = A_{it} \qquad (3.2)$$

In this case, TFP measures the efficiency of the utilisation of capital, labour and materials and the degree of technological advancement associated with economic growth.

Further, following Solow growth model and Ghura and Hadjimichael (1996), technology level, *A*, is assumed to grow according to the following function:

$$A_{it} = A_{i0} e^{\lambda t + R\beta_R} \qquad (3.3)$$

[1] It is an attribute of an effectiveness variable, where it does not affect labour differently from the way it affects capital in the production function.

where λ is the technology growth rate, t the time trend, R the research and development capital (knowledge stock), and β_R the coefficient of R. The subscripts i and t denote the industry and the period respectively.

Since total factor productivity, Y, is equal to the following,

$$Y_{it} = \frac{Q_{it}}{K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M}} \qquad (3.4)$$

substituting equation (3.3) and (3.4) into (3.2), and transforming them into natural logarithm gives:

$$y_{it} = A_o + \lambda t + \beta_R r_{it} + \varepsilon_{it} \qquad (3.5)$$

where variables are written in small letters to signify its value in natural logarithm and ε_{it} is an error term. The R&D variable can be divided into the industry's own R&D and indirect R&D (Los & Verspagen, 2000) from other industries and countries. While Bernstein (1988) uses a simple but crude measure of indirect R&D by taking the unweighted sum of the R&D stocks of all other firms, and Los & Verspagen use patent data, this paper will use a technology flow matrix based upon the 1998 UK industry-by-industry input-output table of intermediate goods. The ratio of use of domestic intermediate goods from other local industries to total production of the individual industries, are used as weights to R&D from other domestic industries.

$$R_{jit}^{d} = \frac{P_{it}}{Q_{it}}\left(R_{jit}^{od}\right) \qquad (3.6)$$

where subscript *j* represents all other industries other than *i*, R^{d}_{jit} is the weighted R&D of other industries, $\frac{P_{it}}{Q_{it}}$ is the weight applicable to R^{od}_{jit}, where P_{it} is the purchase of goods from other local industries, and Q_{it} is the gross output of individual industries, and R^{od}_{jit} is the accumulated R&D expenditures of other domestic industries. In constructing the foreign R&D, R^{f}, I follow Kao et al (1999) and use the ratio of industry imports to its gross domestic product of the previous year as the weights for foreign R&D, as follows,

$$R^{f}_{kit} = \frac{M_{it-1}}{Q_{bt-1}}\left(R^{fm}_{kit}\right) \qquad (3.7)$$

where R^{f}_{kit} is the weighted R&D capital stock of foreign countries, $\frac{M_{it-1}}{Q_{bt-1}}$ is the weight for $\left(R^{fm}_{kit}\right)$ where M_{it-1} is the previous year bilateral industrial imports of goods and Q_{bt-1} is the gross domestic product of UK and $\left(R^{fm}_{kit}\right)$ is total R&D capital stock of foreign countries which are UK's main import partners. The subscript *k* represents all other countries other than *b*, UK. These import partners are the US, Germany, France, Netherlands, Japan, Belgium, Italy, Ireland, Spain, Switzerland, Norway, and Sweden.

The use of R&D capital stock follows Mansfield (1980), Grilliches (1973 and 1980) and Terleckyj (1974). By using the perpetual inventory method, I am assuming that knowledge stock is accumulated through current and past R&D expenditures. The R&D capital stock can be decomposed into the industries own R&D, r^{o}, other domestic R&D, r^{d}, and foreign R&D, r^{f}. Incorporating the fixed effect of industries in α_{i} and dropping *t*, equation 3.5 can be written as

$$y_{it} = \alpha_{i} + \beta_{1} r^{o}_{it-1} + \beta_{2} r^{d}_{it-1} + \beta_{3} r^{f}_{it-1} + \varepsilon_{it} \qquad (3.8)$$

Before running regressions for equation (3.8), (3.10) and (3.11), I check for spurious correlations by performing panel unit root tests based on Levin, Lin and Chu (2002) and Maddala and Wu (1999). In Maddala and Wu (1999), Phillips Perron–Fisher unit root tests are performed. In a spurious regression, the errors would be correlated and the standard t-statistic will be wrongly calculated because the variance of the errors is not consistently estimated. This problem can be detected by looking at the correlogram of the residuals and testing for a unit root on them. In this case, unit root tests are performed to identify the order of integration. This is followed by Kao (1999) and Pedroni (1999) residual-based cointegration tests. In determining which methods to use to test for cointegration, I consider the following arguments. In Larsson et al (2001)'s Monte Carlo simulation, it is found that the test requires a large time series dimension compared to number of cross-section individuals. A small time series dimension would severely distort the size of the test, even if the panel has a large cross-sectional dimension (Gutierrez, 2003). In comparing Kao and Pedroni tests, Gutierrez (2003) finds that for a small sample, Kao test show higher power than Pedroni tests. However, as T gets large, Pedroni tests have higher power than Kao's tests. Since my data is considered as rather small, I choose to report on Kao tests and then compare it with Pedroni tests. Comparatively, both Pedroni and Kao tests performed better than Larsson et al (2001) LR-bar test. Therefore, it is not the scope of this paper to identify the number of cointegrating factors.

To check for robustness of my results, I use two alternative models that originate from the same Cobb-Douglas production function augmented with R&D variables. I use real value added and labour productivity as dependent variables that have industry R&D, other industry R&D and foreign R&D as their regressors besides other essential determinants. In the regression of value added on R&D variables (in natural logarithm), the model is specified as below:

$$v_{it} = \alpha_i + \beta_1 k_{it} + \beta_2 l_{it} + \beta_3 r^o_{it-1} + \beta_4 r^d_{it-1} + \beta_5 r^f_{it-1} + \varepsilon_{it} \tag{3.9}$$

where v is real value added, k is capital stock, and l is number of employees. The β s are the coefficients of all the regressors in the model. As an extension to equation (3.9), the Cobb-Douglas function is divided with the number of employees. This transforms equation (3.9) into the following:

$$(v - l)_{it} = \alpha_i + \beta_1 (k_{it} - l_{it}) + \beta_2 r^o_{it-1} + \beta_3 r^d_{it-1} + \beta_4 r^f_{it-1} + \varepsilon_{it} \tag{3.10}$$

where *(v-l)* is the ratio of output to labour or labour productivity, *(k-l)* is the ratio of capital stock to labour or capital intensity.

3.4 Data Description

This paper uses data on 22 manufacturing industries in the UK for the years 1981-2003. Data are mainly obtained from OECD and ONS datasets. Further description of variables is given in Appendix 3.I. Expenditure on R&D performed in UK businesses dataset is obtained from ONS, whereas total factor productivity is constructed using the Structural Analysis (STAN) Industrial Database of the OECD database based on the international standard industrial code (ISIC), Revision 3. These two datasets are matched in terms of its availability for common cross-section units and time period. Some data on employment are obtained from the Groningen Growth and Development Centre, 60-industry Database[2]. I later drop recycling and furniture industries and 2003 data for cointegration tests due to substantial missing data. This leaves 20 industries and 22 years for the rest of the chapter.

[2] Dated February, 2005.

A well-known issue encountered when estimating the contribution of R&D relates to the problem of double counting of expenditures on labour and physical capital used in R&D in the measures of labour and physical capital used in production. Shankerman (1981) and Mairesse & Hall (1996) point out that the failure to remove this double counting has a downward bias on the estimated R&D coefficients. For this reason, I have adjusted the data so that capital stock and labour exclude those from the R&D expenditure[3].

The summary of the variables are described in Table 3.1. TFP, Y, is derived from the residual after output is regressed on capital, labour and bought-in materials and services. Except for TFP, I find the distribution of all the other variables to be very dispersed, considering their mean. The standard deviation of K/L and R^o, in particular is higher than its mean, whereas VA, K and L are almost as disperse as their mean value. This wide dispersion of data creates a large gap between the minimum and maximum of these variables.

**** Insert Table 3.1 ****

Table 3.2 shows the Pairwise correlations between pairs of variables. The correlation coefficients of regressors with TFP are generally negative. However, with LP they are positive except for the number of employees. Similarly, the correlation coefficients of all regressors with value added are all positive. Other than the number of employees, all regressors correlation coefficients are significantly different from 0. Generally, I can expect many of these regressors to significantly influence their dependent variables in their regressions. The r^o and r^d are strongly related compared to others.

**** Insert Table 3.2 here ****

[3] I have deducted the R&D expenditures from the capital stock, and R&D personnel from the number of employment in each industry.

**** Insert Table 3.3 here ****

The distribution of R&D expenditure to industries and the change in their composition throughout 1981 till 2001 are shown in Table 3.3. Even though the percentage of allocation of R&D expenditure may decrease, it does not necessarily mean that the amount allocated is decreasing. This is evident in Figure 3.1 where the real R&D expenditure allocated for the whole manufacturing sector is increasing every year. At the same time, TFP also experienced an increase.

**** Insert Figure 3.1 here ****

3.5 Results and Discussion

3.5.1 Panel unit root tests

I use two panel unit root tests that have two different characteristics. One, conduct tests assuming that there is a common AR structure for all the series and perform a homogenous unit root test process, and two, conduct tests which allow for different AR coefficients in each series and perform heterogeneous unit root tests. In testing for panel unit root at level, individual fixed effects and trends are included in the model. The individual fixed effects are included to capture the heterogeneity of the industries within the sample.

These two tests are the Levin, Lin and Chu (1999) and Maddala and Wu (1999) tests. See Appendix A for further description of these two tests. Maddala and Wu (1999) use the Phillips Perron-Fisher type test (PPF). Both LLC and (PPF) employ a null hypothesis of a unit root. While Levin, Lin and Chu (LLC) use homogenous unit root process tests and their ρ_i is identical across cross-sections, PPF use heterogeneous unit root process tests and their ρ_i may vary across cross-sections. Under the heterogeneous unit root tests, all the individual unit root tests are combined to derive a panel-specific result.

Table 3.4 shows the results of panel unit root tests perform on all the variables concerned. I include both fixed effects and trends as exogenous regressors. However, as the data graphically show stationarity at first difference, I include fixed effects only in my first difference panel unit root tests. I select lags using Bartlett kernel method (Andrews, 1991) and bandwidth using Newey-West method (Newey and West, 1994). As the TFP is generated from equation (3.2) based on the cost share of inputs, I tested the robustness of my results by applying different depreciation rate, δ, in the perpetual inventory method in the calculation of capital stock. Different δ s evidently cause the mean of TFP to substantially differ, however, their series still show the same trend and non-stationary characteristic. Therefore, I can conclude that, panel unit tests results on TFP are robust at different δ s.

**** Insert Table 3.4 here ****

In Table 3.4, LLC and PPF tests on level data fail to reject the null of a unit root. Using the same procedures for *y*, I test for unit root for other variables that are used in all the models. In both tests, the results on all variables strongly confirm the presence of a unit root except for foreign R&D. While PPF shows that foreign R&D cannot reject the null of a unit root at 10% significance level, LLC t-statistic reject the null of a unit root at 1% significance level. This provide evidence that foreign R&D is integrated of order 0, I(0).

As the variables contain a unit root, i.e. the data is not stationary, I transformed the data to first difference to obtain a stationary pattern and to determine the level of integration for each variable. Similar to the procedure that I apply for all the variables at level, I then perform unit root tests on the first differenced data. The results unanimously conclude that these series are stationary at first difference, as expected. This fulfils the condition for the cointegration test.

3.5.2 Panel cointegration

As my cointegration tests are residual-based, before the cointegration tests are performed, the relevant equations are regressed first. For this purpose, I use equation (3.8), with and without the foreign R&D. From these estimates, I obtain the residuals that I use to perform Kao (1999) and Pedroni (1999) cointegration tests. The results are in Table 3.5. To confirm these results, I further generate residuals from a fully modified OLS estimates. To serve its purpose, only the cointegration tests results are shown in this chapter.

Considering foreign R&D capital, r^f is stationary at levels, I opt to run the cointegration tests with and without the r^f, to see how that would affect the results of my tests. In Table 3.5, panels 1 and 3 indicate the results when r^f is omitted, whereas panels 2 and 4 indicate results when r^f is included. I find that this does not alter my cointegration results substantially. The variables are still cointegrated in their respective regressions. Thus, it does not make much difference in the results of the tests to either include or exclude r^f.

**** Insert Table 3.5 here ****

In Kao tests, the DF_ρ and DF_t statistics are for the cointegration based on the strong exogeneity of the regressors and errors. DF_ρ^* and DF_t^*, on the other hand, are for the cointegration with endogenous relationship between them. All the four tests using bias-corrected OLS residuals conclude to reject the null hypothesis of no cointegration which means the variables are cointegrated according to these tests. Kao ADF test also shows similar results. The fully modified OLS residuals using the DF and ADF type tests indicate similar results. Kao (1999) tests assume homogenous slope coefficients, while Pedroni (1999) tests assume them to be heterogenous.

In Pedroni tests, most of the results reject the null of cointegration, with the exception of one of the panel v-statistics and panel ρ-statistics, and two of the group ρ-statistics. As these statistics are known to have low power in small panels, I prefer to use the results that are reflected by most of Pedroni's test. As these results are consistent to Kao's tests, I can conclude that both Kao and Pedroni tests predict the existence of long run relationship in the bias-corrected OLS and fully modified OLS regressions.

**** Insert Table 3.6 here ****

In Table 3.6, I further test the robustness of these results using the labour productivity models. The results are similar and therefore confirm that R&D and productivity (both total factor productivity and labour productivity) are cointegrated. Hence, I predict a long run steady state relationship between R&D and productivity, and this is consistent to the economic theory. Another robustness check is performed using equation (3.10), with value added as the dependent variable. It proves that R&D and value added are cointegrated and the results are shown in Table 3.7.

**** Insert Table 3.7 here ****

As the data are cointegrated, I can now run my regressions at levels. I am assured that the regressions will give correct information and coefficients even if one of the independent variable, i.e. foreign R&D is not cointegrated. (See Mosconi and Giannini, 1992)

3.5.3 Elasticities and R&D Intensity

When I regress TFP on R&D, the results in general has a rather inconclusive effect on TFP. In Table 3.8, variables r^o and r^d are found to be significant only when lagged three periods, whereas r^f when lagged one period. However, the sign of the industries own R&D and foreign R&D coefficients is a puzzle. Instead of the expected positive sign, it is negative. On the other hand, r^d is positive and its coefficients and significance seem to be improving with time. This shows that the lag structure is important in determining the relationship between domestic R&D and TFP. Process and product R&D of various industries are expected to have different gestation periods. Pharmaceutical industry, for instance, are known to have a very long lag between its product R&D and realised sales, partly due to regulatory factors. Hence, including higher lags potentially improve the importance of domestic R&D expenditures to TFP.

**** Insert Table 3.8 here ****

Generally, the F-statistics of the regressions in Table 3.8 show that the R&D variables poorly explain the variations in TFP and regressions 2 and 3 cannot reject the null of R^2=0. These results require me to collect more evidence to confirm their robustness. I test on the possibility of the R&D intensive industries to see if it shows more convincing results. The R&D intensive industries usually have innovation history and therefore accumulate technological advantages, such as the attitude of the management and employees towards innovation and their general ability to implement change. According to Malerba et al (1997), the ability to innovate among the innovative firms is persistent and firm-specific and these make them qualitatively different from the non-innovating firms.

To investigate on this possibility, I first identify the R&D intensity of each industry by calculating the ratio of R&D expenditure to output averaged throughout the period under study. The ranking of individual R&D intensity is shown in Table 3.9. Second, as the average R&D intensity of all industries in my dataset is 3.1%, I identify the industries that are considered as R&D intensive as those with more than 4%. They are pharmaceutical (17.50%), aircraft and spacecraft (10.81%), radio, television and communication equipment (6.32%), electrical machinery and apparatus, n.e.c. (4.37%), office, accounting and computing machinery (4.16%) and medical, precision and optical instruments (4.06%). Thirdly, I create a dummy for the R&D intensive industries. This dummy is interacted with the individual own R&D capital stock. I include this interaction term in regression 4 in Table 3.8. This regression shows that the R&D intensity of the industry does not have significant impact on TFP. Besides that, the sign remains negative.

To compare the industries data with the total economy, I run regressions of total economy TFP growth[4] on total domestic business expenditure on R&D growth (DBERDG)[5] and foreign R&D expenditure growth and they confirm that DBERDG has a reasonably high positive coefficient at 5% significance level. The industry level results are a puzzle considering widely known positive R&D effect on the UK TFP. Further, Griliches and Mairesse (1983), who obtain similar results for their US industries data, suggest the negative results may be due to the US turbulent time during 1967-78 and also to problems of

[4] Obtained from O'Mahony and van Ark (2003) dataset.
[5] Obtained from OECD Main Science and Technology Indicators, 2006.

measurement. In their paper, they acknowledge the possibility of their negative results to the problem of double counting the R&D-related employees and R&D-related capital expenditures in their actual measure of labour and physical capital stock. However, in this chapter, I have treated the data accordingly to avoid the double counting and there is no 'turbulent' period covered in my data, but the results still provide evidence of either a negative or inconclusive relationship. These puzzling results may be due to the inability of a firm to appropriate all the benefits of its own R&D investment and this has been recognised as a distinctive feature of R&D (see Griliches, 1979; and Spence 1984).

Scherer (1982) explains that internal process work development and the purchase of R&D-embodying products in one industry should lead directly to measured productivity growth for that industry. However, for product R&D, much of the benefit from one industry's superior new products will be passed on to buyers in another industry. This explains the significant positive coefficients of other industries' R&D on TFP. Hence, one would not expect to find a significant relationship between product R&D and productivity growth unless there are raising prices over cost margins associated with innovators' monopoly power and/or systematic mismeasurement. According to Scherer, the increase in the prices of improved products and revenue from new products are absorbed by price deflators and productivity indices. Further, in competitive markets, as new and better products enter the market, earlier products' prices become cheaper. As my data is in constant currencies, not volume, these reasons offer a sensible explanation to this puzzle.

**** Insert Table 3.9 here ****

As my results on the industry own R&D and foreign R&D does not conform to the country level results (see Coe and Helpman (1995), Kao et al (1999) and

Guellec and van Pottelsberghe de la Potterie (2001)), it motivates me to investigate the robustness of these results on another productivity measurement, namely labour productivity, and value added. I apply the same treatment on equation (3.9) (see Table 3.10) and equation (3.10) (see Table 3.11) and I find that, even though the coefficients are much smaller, the r^os remain negative. In regressions 2 to 4 in Tables 3.10 and 3.11, r^o and its interaction tem show consistently negative signs. I can also conclude that the R&D intensity of these industries in these three models does not make much difference to their coefficients. Cameron (2006) also shows negative coefficients for R&D capital for his UK sectoral TFP regressions. He uses OLS and WLS regressions. However, he did not address the issue of the negative sign of the industry own R&D coefficients. On the other hand, Anon Higon (2004) results on 8 UK manufacturing industries find significant positive R&D coefficients in the long run, but negative and insignificant foreign R&D.

The foreign R&D coefficients, contrary to the TFP model, are significantly positive in both equations (3.9) and (3.10). This confirms that my results in the TFP models are not robust in the other two models. On the whole, the results in Tables 3.10 and 3.11 show that the positive sign of r^d is robust in all the regressions in these two models. These results tell us the benefits of knowledge generated in one industry are not confined to that industry but it spills over to other industries that incorporate the freely obtained knowledge into their production process (see Bernstein, 1989). This R&D spillovers cause autonomous technological change to the receiving industry and thereby reduce their cost of production. Compared to my results in Table 3.8, R&D can explain the variations in labour productivity and value added much better than TFP. This is evident from their R^2s, especially the within and overall R^2s, which are much better than those in the TFP models and therefore provide evidence that the regressors strongly explain the variations in LP and VA.

**** Insert Table 3.10 and Table 3.11 here ****

Due to the consistently negative sign of the industry own R&D, r^o, coefficients in all the regressions, and being fully aware that this sign is not consistent to economic theory, I examine the elasticities of the industry own R&D separately for each individual industry based on equations 3.8, 3.9 and 3.10, to find the source of such results. I believe that not all industries have the negative sign as captured in the panel data regressions. Therefore, the regressions are based on the times series and not on the panel data setting. The summary of the results is shown in Table 3.12.

**** Insert Table 3.12 here ****

In Table 3.12, under the TFP column, the sign of the industries r^o coefficients are mostly negative and only seven are positive. Even though four of them are significantly positive, the insignificance and negative sign substantially outweigh the positive. This explains the relatively higher negative coefficients in the case of TFP. In the case of LP and VA, even though there are many positive signs and some of them are significant coefficients, the negative appear to marginally outweigh the positive, hence, the results that I have in Tables 3.10 and 3.11.

3.6 Conclusions

In this chapter, I examine whether R&D has a long run relationship with productivity. As commercially-oriented innovation efforts are the major engine of technological progress and productivity growth, it is essential to look into the different forms (sources) of R&D as the determinants of total factor productivity. In a simple closed economy, a country's own R&D brings about more effective use of existing resources and thereby raises its productivity level. However, in an open economy, a country's trading partners' R&D is also important besides its own R&D. The R&D efforts of its trading partners are transmitted mainly through international trade and foreign direct investment.

My results provide evidence that the manufacturing industries in the UK benefit from other domestic industries R&D and foreign R&D spillovers but not their own R&D activities. Unlike the positive impact of domestic R&D on TFP at country level, the industry R&D has a negative impact on its TFP. This result proves the industry does not rely on its own R&D to improve its productivity but rather the collective R&D efforts of all industries in the economy. Even though the industry's R&D is a cost to the industry, it is still crucial for each industry to perform their R&D due to its social returns. Due to its public good nature, other industries seem to be benefiting collectively from the R&D efforts of domestic industries within the economy. This makes it important for every industry to pursue their R&D efforts even though it has a negative impact on its own industry. In this sense, there is a long run relationship between domestic and foreign R&D and total factor productivity.

TABLES AND FIGURES

Table 3.1 :
Data Description

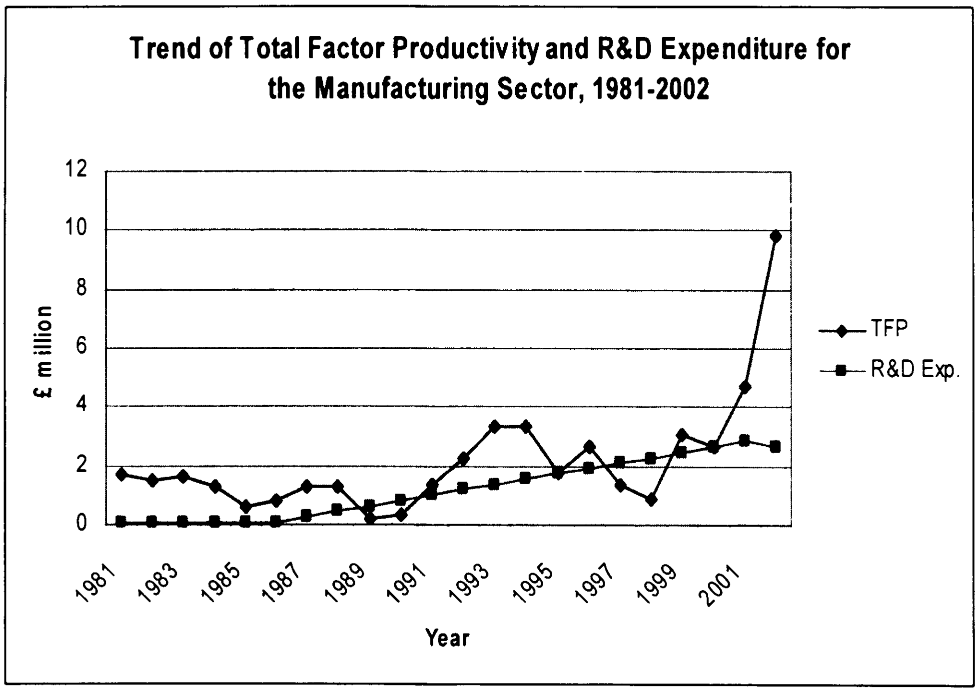
Variable	Mean	Standard Deviation	Minimum	Maximum
Y	4.8	12.6	.1	139.5
V/L	2,638.3	1,999.2	272.6	10,747.7
V	441,028.6	418,002.2	19,920.63	2,149,122
K	1,013,803	1,004,329	12,129.8	4,874,405
L	198.1	163.8	16	700
K/L	8,133.6	11,293.7	226.1	64,983.5
R^o	410.1	488.2	13.9	3,127.1
R^d	1,615.6	1,116.3	442.1	13,624.2
R^f	3,825.8	2,995.0	36.7	15,752.6

Notes : Y - total factor productivity (index), V/L – labour productivity (euros), V – real value added (euros), K – capital stock (euros), L – number of employees (persons), K/L – ratio of capital stock to labour(capital intensity), R^o - industry own R&D capital stock (£ sterling million), R^d – weighted other domestic industries R&D capital stock (£ sterling million), R^f – weighted foreign R&D capital stock (constant 2000 US$ mil and at PPP).

Table 3.2 :
Pairwise Correlation

	y	v-l	v	k	l	k-l	r^o	r^d	r^f
y	1.0000								
v-l	-0.3941	1.0000							
v	-0.2976	0.5488	1.0000						
k	-0.6244	0.5440	0.8938	1.0000					
l	0.0914	-0.0979	0.6423	0.4834	1.0000				
k-l	-0.7498	0.6689	0.4106	0.6609	-0.3375	1.0000			
r^o	-0.2419	0.7768	0.4585	0.3866	-0.1805	0.5705	1.0000		
r^d	-0.2337	0.8024	0.4761	0.3943	-0.1930	0.5894	0.9800	1.0000	
r^f	-0.2801	0.2349	0.4975	0.5216	0.2874	0.3145	0.1606	0.1672	1.0000

Notes : All values are in natural logarithm. y - total factor productivity, v-l – labour productivity, v – real value added, k – capital stock, l – number of employees, k-l – ratio of capital stock to labour (capital intensity), r^o - industry own R&D capital stock, r^d – weighted other domestic industries R&D capital stock, r^f – weighted foreign R&D capital stock.



Trend of Total Factor Productivity and R&D Expenditure for the Manufacturing Sector, 1981-2002
12
10
8
6
4
2
0
£ million
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
Year
TFP
R&D Exp.

Figure 3.1

Table 3.3 :
Ratio of Industry R&D Expenditure to Manufacturing Total

	Industries	1981	1986	1991	1996	2001
1	Food products and beverages	0.0303	0.0284	0.0308	0.0273	0.0321
2	Textiles, textile products, leather and footwear	0.0045	0.0049	0.0036	0.0037	0.0017
3	Pulp, paper, paper products, printing and publishing	0.0064	0.0064	0.0068	0.0078	0.0035
4	Coke, refined petroleum products and nuclear fuel	0.0415	0.0396	0.0390	0.0317	0.0255
5	Chemicals excluding pharmaceuticals	0.0878	0.0951	0.1111	0.0863	0.0533
6	Pharmaceuticals	0.0961	0.1150	0.1883	0.2549	0.3106
7	Rubber and plastics products	0.0096	0.0068	0.0055	0.0092	0.0046
8	Other non-metallic mineral products	0.0112	0.0090	0.0069	0.0083	0.0042
9	Iron and steel	0.0102	0.0081	0.0063	0.0054	0.0032
10	Non-ferrous metals	0.0070	0.0043	0.0038	0.0021	0.0019
11	Fabricated metal products, except machinery and equipment	0.0121	0.0105	0.0075	0.0125	0.0065
12	Machinery and equipment, n.e.c.	0.1169	0.0753	0.0770	0.0794	0.0861
13	Office, accounting and computing machinery	0.0402	0.0656	0.0514	0.0222	0.0107
14	Electrical machinery and apparatus, nec	0.0728	0.0990	0.0814	0.0674	0.0461
15	Radio, television and communication equipment	0.1140	0.1323	0.0760	0.0911	0.1067
16	Medical, precision and optical instruments, watches and clocks	0.0584	0.0505	0.0434	0.0423	0.0499
17	Motor vehicles, trailers and semi-trailers	0.0652	0.0898	0.0950	0.1275	0.0917
18	Building and repairing of ships and boats	0.0057	0.0024	0.0025	0.0028	0.0085
19	Aircraft and spacecraft	0.2038	0.1507	0.1579	0.1118	0.1287
20	Railroad equipment and transport equipment n.e.c.	0.0022	0.0021	0.0027	0.0041	0.0212
21	Furniture; manufacturing n.e.c.	0.0038	0.0038	0.0031	0.0022	0.0032
22	Recycling	0.0000	0.0002	0.0002	0.0001	0.0001

Note: n.e.c. is the abbreviation of not elsewhere classified.

Table 3.4 :
Panel Unit Root Tests, with Individual Effects and Individual Linear Trends

Variables	Levin, Lin and Chu#		Phillips Perron-Fisher~	
	Level	**Difference**	**Level**	**Difference**
y	0.53073	-13.5767	42.2667	343.649
	(0.7022)*	(0.0000)	(0.5461) *	(0.0000)
$v\text{-}l$	-3.5780	-15.9272	12.7114	182.092
	(0.0002)	(0.0000)	(1.0000) *	(0.0000)
v	2.1404	-14.8316	12.3304	172.406
	(0.9838) *	(0.0000)	(1.0000) *	(0.0000)
k	0.2419	-12.6310	17.9418	167.097
	(0.5956) *	(0.0000)	(0.9948) *	(0.0000)
l	0.8588	-14.3534	20.4093	190.680
	(0.8048) *	(0.0000)	(0.9912) *	(0.0000)
$k\text{-}l$	0.7038	-14.1717	19.2557	253.267
	(0.7592) *	(0.0000)	(0.9899) *	(0.0000)
r^o	0.24850	-18.1659	53.8977	364.166
	(0.5981) *	(0.0000)	(0.1457) *	(0.0000)
r^d	3.32155	-16.5395	13.9839	222.512
	(0.9996) *	(0.0000)	(1.0000) *	(0.0000)
r^f	-2.95295	-10.7412	52.4413	184.444
	(0.0016)	(0.0000)	(0.0899) *	(0.0000)

Notes:
(1) # t-stat
(2) ~ Chi-square
*(3) * Cannot reject the null hypothesis of unit roots*
(4) p-values in parentheses
(5) At levels, total observations = 945, at first difference = 882
(6) At level, the tests are performed with individual effects and linear trends, whereas at first difference, the tests are performed with individual effects only.

Table 3.5 :
Kao and Pedroni Panel Cointegration Test
Dependent Variable: Total Factor Productivity

Type of Tests	Bias-Corrected OLS Without r^f	Bias-Corrected OLS With r^f	Fully Modified OLS Without r^f	Fully Modified OLS With r^f
Kao DF (1999)				
DF_ρ	-28.3780	-20.3598	-28.4741	-24.8302
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_t	-18.7659	-12.8139	-18.8393	-15.9970
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF^*_ρ	-21.1261	-26.1313	-21.1615	-24.4525
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF^*_t	-18.0029	-12.8991	-18.0697	-15.9771
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Kao ADF test	-6.0708	-9.2805	-6.2122	-11.3054
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Pedroni (1999)				
Panel v-statistic	69.33058	28.6562	66.1675	14.8346
	(0.0505)	(0.0006)	(0.0917)	(0.0000)
Panel ρ-statistic	-84.7715	-65.1897	-87.1993	-84.2569
	(0.0000)	(0.2568)	(0.0000)	(0.0028)
Panel t-statistic	-18.2809	-16.2099	-19.1161	-24.9488
(non-parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel t-statistic	-34.8757	-301.0106	-36.0240	-554.4769
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group ρ-statistic	-78.3958	-69.8775	-79.4042	-81.4269
	(0.0021)	(0.2452)	(0.0013)	(0.2356)
Group t-statistic	-17.9544	-16.9622	-17.9650	-22.8118
(non-parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group t-statistic	-17.6651	-17.7792	-18.1665	-23.0350
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes:
(1) The bias-corrected t-ratio are reported in parentheses for each variable.
(2) P-values are reported in parentheses for Kao and Pedroni tests.
*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

Table 3.6 :
Kao and Pedroni Panel Cointegration Test
Dependent Variable: Labour Productivity

Variable	Bias-Corrected OLS		Fully Modified OLS	
	Without r^f	With r^f	Without r^f	With r^f
Kao DF (1999) Tests				
DF_ρ	-20.3598	-20.0328	-24.8302	-24.9318
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_t	-12.8139	-12.5975	-15.9970	-16.0647
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_ρ^*	-26.1313	-26.4307	-24.4525	-24.5683
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_t^*	-12.8991	-12.6612	-15.9771	-16.0458
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Kao ADF test	-9.2805	-8.3901	-11.3054	-11.3793
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Pedroni (1999) Tests				
Panel v-statistic	28.6562	26.3373	14.8346	14.8375
	(0.0006)	(0.0000)	(0.0000)	(0.0000)
Panel ρ -statistic	-65.1897	-65.9455	-84.2569	-85.3079
	(0.2568)	(0.1390)	()	(0.1954)
Panel t-statistic	-16.2099	-16.4641	-24.9488	-24.8858
(non-parametric)	(0.0000)	(0.0001)	(0.0000)	(0.0000)
Panel t-statistic	-301.0106	-324.3696	-554.4769	-558.5813
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group ρ -statistic	-69.8775	-68.3309	-81.4269	-81.6350
	(0.2452)	(0.0029)	(0.2356)	(0.1004)
Group t-statistic	-16.9622	-16.7534	-22.8118	-22.9096
(non-parametric)	(0.0000)	(0.0002)	(0.0000)	(0.0000)
Group t-statistic	-17.7792	-17.4748	-23.0350	-23.1659
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes:
(1) The bias-corrected t-ratio are reported in parentheses for each variable.
(2) P-values are reported in parentheses for Kao and Pedroni tests.
*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

Table 3.7 :
Kao and Pedroni Panel Cointegration Test
Dependent Variable: Value Added

Variable	Bias-Corrected OLS		Fully Modified OLS	
	Without r^f	With r^f	Without r^f	With r^f
Kao DF (1999) Tests				
DF_ρ	-27.0434	-27.0421	-27.3951	-27.3635
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_t	-17.1426	-17.1443	-17.3865	-17.3671
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_ρ^*	-52.1938	-52.3202	-51.8654	-52.2007
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF_t^*	-12.3849	-12.3089	-13.0537	-12.8340
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Kao ADF test	-3.3186	-3.2341	-5.6195	-5.1712
	(0.0005)	(0.0006)	(0.0000)	(0.0000)
Pedroni (1999) Tests				
Panel v-statistic	11.9849	10.5440	8.2591	8.2547
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel ρ-statistic	-112.3590	-110.2919	-110.0700	-108.7123
	(0.0001)	(0.0677)	(0.0004)	(0.0888)
Panel t-statistic	-35.4108	-33.7207	-31.5314	-33.5187
(non-parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel t-statistic	-336.1368	-320.7839	-236.9383	-269.5724
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group ρ-statistic	-110.4846	-105.6459	-109.9964	-108.3763
	(0.0280)	(0.2998)	(0.0317)	(0.4025)
Group t-statistic	-35.7961	-37.2149	-36.3538	-38.0042
(non-parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group t-statistic	-156.3494	-150.4229	-118.9656	-132.3868
(parametric)	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes:
(1) The bias-corrected t-ratio are reported in parentheses for each variable.
(2) P-values are reported in parentheses for Kao and Pedroni tests.
*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

Table 3.8 :
Marginal Effect of R&D on TFP

Variable		(1)	(2)	(3)	(4)
Constant		2.9474	0.4973	-0.2897	1.9704
		(1.1908)	(1.2844)	(1.0608)	(1.9844)
r^o (t-1)		-0.1972			
		(0.1448)			
r^o (t-2)			-0.2399		
			(0.1498)		
r^o (t-3)				-0.2621	
				(0.1041) *	
r^d (t-1)		0.1493			0.0498
		(0.1631)			(0.3101)
r^d (t-2)			0.2299		
			(0.1680)		
r^d (t-3)				0.3312	
				(0.1235)**	
r^f (t-1)		-0.3212			-0.0033
		(0.1555)*			(0.4447)
r^f (t-2)			-0.0948		
			(0.1488)		
r^f (t-3)				-0.1405	
				(0.1461)	
$rdi*r^o$					-0.2019
					(0.2504)
R^2 :	**within**	0.0599	0.0179	0.0172	0.0710
	between	0.1317	0.0402	0.0526	0.1849
	overall	0.0912	0.0274	0.0324	0.0248
F-stat		6.05	1.87	2.45	3.30
(P value)		(0.0005)	(0.1349)	(0.0631)	(0.0235)
Observations		419	399	379	105

Notes:

(1) P-values are reported in parentheses.

*(2) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

(3) Robust standard error is applied.

Table 3.9 :
Ranking of Average R&D Intensity of Manufacturing Industries (1981-2002)

Rank	Industries	**R&D Intensity (%)**
1	Pharmaceuticals	17.50
2	Aircraft and spacecraft	10.81
3	Radio, television and communication equipment	6.32
4	Electrical machinery and apparatus, nec	4.37
5	Office, accounting and computing machinery	4.16
6	Medical, precision and optical instruments, watches and clocks	4.06
7	Motor vehicles, trailers and semi-trailers	2.68
8	Chemicals excluding pharmaceuticals	2.37
9	Machinery and equipment, n.e.c.	2.27
10	Railroad equipment and transport equipment n.e.c.	2.22
11	Coke, refined petroleum products and nuclear fuel	1.78
12	Building and repairing of ships and boats	1.05
13	Other non-metallic mineral products	0.55
14	Non-ferrous metals	0.42
15	Iron and steel	0.41
16	Rubber and plastics products	0.38
17	Food products and beverages	0.36
18	Fabricated metal products, except machinery and equipment	0.33
19	Textiles, textile products, leather and footwear	0.15
20	Pulp, paper, paper products, printing and publishing	0.13

Note:
(1) R&D intensity is the ratio of R&D expenditure to gross output multiplied by 100.

Table 3.10 :
Marginal Effects of R&D on Labour Productivity

Variable	(1)	(2)	(3)	(4)
Constant	-0.1100	0.0879	0.3681	-0.3992
	(.2254)	(.2607)	(.2740)	(0.3152)
k-l	0.3081	0.2855	0.3007	0.2379
	(0.0409) **	(0.0420) **	(0.0416) **	(0.0682)**
r^o (t-1)	-0.1144			
	(0.0378) **			
r^o (t-2)		-0.0977		
		(0.0421) *		
r^o (t-3)			-0.0969	
			(0.0408) *	
r^d (t-1)	0.3996			0.4689
	(0.0536) **			(0.0887) **
r^d (t-2)		0.3675		
		(0.0583) **		
r^d (t-3)			0.3467	
			(0.0569) **	
r^f (t-1)	0.1231			0.0934
	(0.0602) *			(0.0638)
r^f (t-2)		0.1643		
		(0.0523) **		
r^f (t-3)			0.1545	
			(0.0546) **	
rdi*r^o				-0.0961
				(0.0642)
R^2 : within	0.9183	0.9142	0.9039	0.9614
between	0.6655	0.5559	0.5878	0.2901
overall	0.8512	0.8126	0.8051	0.8704
F-stat	942.69	888.21	773.30	519.32
(P value)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	419	399	379	105

Notes:

(1) P-values are reported in parentheses.

*(2) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

(3) Robust standard error is applied .

Table 3.11 :
Marginal Effect of R&D on Value Added

Variable	(1)	(2)	(3)	(4)
Constant	4.1874	3.9816	3.8028	2.3225
	(0.7220)	(0.6927)	(0.8102)	(0.7649)
k	0.2475	0.2477	0.2730	0.2059
	(0.0371) **	(0.0381) **	(0.0392) **	(0.0594)**
l	0.0543	0.1152	0.1662	0.2905
	(0.0935)	(0.0972)	(0.1082)	(0.1678)
r^{o} *(t-1)*	-0.0767			
	(0.0297) **			
r^{o} *(t-2)*		-0.0759		
		(0.0316) *		
r^{o} *(t-3)*			-0.0853	
			(0.0321) **	
r^{d} *(t-1)*	0.3170			0.4121
	(0.0403) **			(0.1005) **
r^{d} *(t-2)*		0.3019		
		(0.0416) **		
r^{d} *(t-3)*			0.2969	
			(0.0420) **	
r^{f} *(t-1)*	0.1745			0.1621
	(0.0499) **			(0.0754) *
r^{f} *(t-2)*		0.1942		
		(0.0435) **		
r^{f} *(t-3)*			0.1688	
			(0.0463) **	
$rdi*r^{o}$				-0.0926
				(0.0720)
R^2 : within	0.9045	0.8953	0.8744	0.9517
between	0.8180	0.8630	0.9074	0.9368
overall	0.7672	0.8215	0.8640	0.9185
F-stat (P value)	615.51 (0.000)	561.39 (0.000)	477.93 (0.000)	377.61 (0.000)
Observations	419	399	379	105

Notes:
(1) P-values are reported in parentheses.
*(2) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*
(3) Robust standard error is applied.

Table 3.12 :
Individual Industry Elasticity of Output with Respect to its R&D

	Industries	Dependent Variables					
		TFP		Labour Prod.		Value Added	
		Sign	Sigfc.	Sign	Sigfc.	Sign	Sigfc.
1	Food products and beverages	-	x	+	x	+	x
2	Textiles, textile products, leather and footwear	-	x	+	x	+	√*
3	Pulp, paper, paper products, printing and publishing	-	x	-	x	-	x
4	Coke, refined petroleum products and nuclear fuel	-	x	-	x	+	x
5	Chemicals excluding pharmaceuticals	-	x	-	x	-	x
6	Pharmaceuticals	-	x	+	√*	+	√*
7	Rubber and plastics products	-	x	+	x	+	x
8	Other non-metallic mineral products	-	x	+	x	+	x
9	Iron and steel	-	x	+	√*	+	x
10	Non-ferrous metals	-	x	+	x	+	x
11	Fabricated metal products, except machinery and equipment	+	x	-	x	+	x
12	Machinery and equipment, n.e.c.	-	x	-	x	+	√*
13	Office, accounting and computing machinery	+	x	-	x	+	x
14	Electrical machinery and apparatus, nec	+	√*	-	x	+	x
15	Radio, television and communication equipment	+	√*	+	x	+	x
16	Medical, precision and optical instruments, watches and clocks	+	√*	+	√**	+	√**
17	Motor vehicles, trailers and semi-trailers	-	x	+	x	-	x
18	Building and repairing of ships and boats	+	√*	+	√**	+	√**
19	Aircraft and spacecraft	+	x	+	x	+	x
20	Railroad equipment and transport equipment n.e.c.	-	√*	-	√*	-	x

Notes:
(1) - indicate a decreasing effect.
(2) + indicate an increasing effect.
(3) x indicate the coefficients are not significant at 5% significance level.
(4) √ indicate the coefficients are significant at 5% significance level
*(5) Significant coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

Appendix 3.I

DATA DESCRIPTION

In the Frascati Manual[6], R&D is defined as "comprising creative work undertaken on a systematic basis in order to increase stock of knowledge and the use of this stock of knowledge to devise new applications". Due to the absence of R&D capital stock data, I construct R&D capital stock from R&D expenditures, deflated over time using the Producers Price Index (1995), and using the perpetual inventory method, as follows,

$$R_t = (1-\delta)R_{t-1} + I_t$$

where R_t represents the current R&D capital stock, δ is the rate of R&D capital depreciation, R_{t-1} is the R&D capital stock in the previous year and I_t is real R&D expenditure. I estimate an initial value of the 1979 capital stock for each industry as $R_{1979} = \dfrac{I_{1980}}{(g+\delta)}$, where g is calculated as the average geometric growth rate from 1980 to 2003, under the assumption that over long periods of time, capital and output grow at the same rate. A depreciation rate of 6% is assumed[7].

Foreign R&D is obtained from the weighted gross domestic expenditure on R&D of main exporters to the UK, namely, the US (13.4% of UK imports), Germany (12.6%), France (8.0%), Netherlands (6.9%), Japan (4.8%), Belgium (4.6%), Italy (4.4%), Ireland (4.3%), Spain (2.7%), Switzerland (2.6%), Norway (2.6%), and Sweden (2.2%). These countries represent about 70% of total imports of UK, which is based on IMF 2000 bilateral direction of trade data and expected to significantly represent the spillover effects of foreign

[6] OECD, 1993, p.29.
[7] Following the assumption of Hall and Jones (1999).

R&D activities. The weights are based on the ratio of imports of each industry to the UK total imports.

Value added is equal to production minus intermediate inputs, and comprises of labour costs, consumption of fixed capital, indirect taxes less subsidies and net operating surplus and mixed income. In calculating for labour productivity, I divide value added with the number of employees.

Physical capital stock is constructed from gross fixed capital formation, and treated in the same way as the R&D capital stock is constructed from R&D expenditure. Capital intensity is physical capital stock divided by the number of full time employees.

CAUSALITY BETWEEN EXPORTS AND PRODUCTIVITY

Abstract

Empirical evidence linking exports and productivity growth has been mixed and inconclusive. This study re-examines the direction of the causality between them for Malaysian industries by using the error-correction mechanism and Granger causality models. By including other variables like size and capital intensity in my models, I have captured the indirect effects besides the direct effects between exports and productivity. In a panel of 63 manufacturing industries, for the period of 1981 to 1999, I find that these industries support the export-led growth and the growth-driven export hypotheses. A further look into the results indicates that there are possibilities of indirect causalities between productivity growth and export through size and capital intensity, as both exports and labour productivity have bidirectional causality with size and capital intensity.

JEL classifications: C33, D24, L60, O40
Keywords: Exports, Productivity growth, Causality, Panel data, Manufacturing industries.

4.1 Introduction

The relationship between exports and productivity growth is a much debated topic. Many studies[1] have found overwhelming evidence for the contemporaneous correlation between export growth and either GDP or productivity growth. Contemporaneous correlation does not necessarily indicate causality and, even if there is causality, it is not identified. Causality needs to be identified. In addition, the direction of this causality, either productivity growth causes exports to grow, or vice versa, needs to be affirm. Balassa (1978a) and Feder (1983), for instance, implicitly imply a possibility of causality from export to output. They test the export-led growth hypothesis by

[1] For instance, Maizels (1963) pooled 7 developed countries, Kravis (1970) pooled 37 non-oil exporting LDCs, Michaely (1977) pooled 41 countries, Balassa (1978a, 1978b) on 11 countries and Kavousi (1984) pooled 73 countries, to name a few.

adopting an augmented production function approach which in addition to the traditional inputs, capital and labour, includes export as one of the determinants of output. Following their works, later empirical studies[2] attempt to determine the causal link between exports and GDP by adopting the concept of causality proposed by Granger (1969) and Sims (1972). While Jung and Marshall (1985) and Darrat (1986) among others find output may also cause export, Sung-Shen et al (1990) and Afxentiou and Serletis (1991) find that export and output have bidirectional causality. Giles and Williams (2000), in their comprehensive survey, report that the results of some countries differ from others. These results may either confirm the export-led growth or growth-led hypothesis, or both. These differences in results might be due to the different time periods, frequencies, methods and variable selections, or to the nonstationarity and (co)integrated properties that are used to run the causality tests. It is more of a statistical problem than an economic one. Therefore, an appropriate degree of caution must be considered before these results are interpreted (Yamada, 1998).

Due to these differences in findings, this chapter re-examines the causality between productivity and exports in the case of Malaysian manufacturing industries for the period of 1980-1999. It reaffirms whether these variables have a unidirectional or bidirectional causality. Analysing the direction of causality of export and productivity is important in determining whether there is a feedback in their causality. Further, to address the problem of spurious regressions that gives misleading estimates, I run unit root and cointegration tests. Only the variables that are found cointegrated, are further regressed in the error-correction and Granger bivariate and multivariate causality models. These results would provide evidence whether the variables have a short-run as well as a long-run causality.

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[2] Jung & Marshall (1985), Hsiao (1987), Kugler (1991), Ahmad & Harnhirun (1992), Bahmani-Oskooee & Alse (1993) and Dodaro (1993) adopt Granger (1969); Gupta, (1985), and Chow (1987) adopt Sims (1972), to name a few.

4.2 Brief Literature Review

The study of causality between productivity and exports brings us to the export-led growth and growth-driven export hypotheses. In particular, export-led growth (ELG) hypothesis reflects the fact that export can be a catalyst for output growth both directly, as a component of aggregate output, and indirectly through efficient resource allocation, greater capacity utilisation, stimulation of technological improvement and exploitation of economies of scale due to foreign market competition (Awokuse, 2003). This is also termed as 'learning-by-exporting' or 'learning-by-doing' process where exporting activities will result in the firms and industries becoming more productive. An increase in exports may loosen a foreign exchange constraint (Chenery and Strout, 1966) which makes it easier to import inputs to meet domestic demand and enable output expansion. Outward expansion makes it possible to use external capital for development and may assist with debt servicing (Hart, 1983). Besides that, Balassa (1978b) and Buffie (1992) found that, in a capital imperfect market, exports provide foreign exchange that allows for increasing levels of capital formation and thus stimulate output growth. This exposure may serve as a means to transfer technology from abroad and further generate spillover effects into the rest of the economy as efficiency improves and productivity grows.

On the other hand, the growth-driven export hypothesis, which means reverse causal flow from output to exports, suggests that those would-be exporters would prepare themselves to be more competitive and productive before they enter the exports market to ensure survival in the highly competitive export market. To compete, many of these firms realise the benefit of economies of scale. Because of this, it is typical to find many manufacturing exporters being larger than non-exporters and more productive before they entered export market.

As one might expect, these hypotheses do have sound economic theory bases. The ELG hypothesis, for instance, is supported by the trade theory. This theory suggests exposure to greater competitive pressures and extended market base could result in the more efficient use of existing resources, and promotes the transfer and diffusion of technical knowledge in the long run (Helpman & Krugman, 1985; Grossman & Helpman, 1991; Greenaway & Kneller, 2004). Exports growth, especially of goods in the production of which a country has comparative advantage, may allow firms to benefit from economies of scale through specialisation in the production of export products. The skills of workers rise and this increases their productivity.

The growth-driven export hypothesis, on the other hand, is supported by the technology theories of trade, which propose a causal link running from productivity to trade rather than the other way around. These theories suggest that competitive performance in export markets are driven by market power which is mainly achieved through innovation (Vernon, 1966 and 1979). The would-be exporters prepare themselves to be more competitive and productive before they enter the exports market to ensure survival in the highly competitive export market. To compete, many of these firms realise the benefit of economies of scale. Hence, it is typical to find many manufacturing exporters being larger than non-exporters and more productive before they entered the export market. Following this growth-driven export mechanism, Sung-Shen et al (1990) and Afxentiou and Serletis (1991) provide evidence of a feedback. They find that exporters improve further through the 'learning-by-exporting' process. More recent research (e.g. Feenstra (2001) and Melitz (2003)) suggest that as more firms opened up to export trade, other firms within the industry would also rationalise themselves and therefore, result in productivity gains at the level of the industry. Resources are reallocated from the less efficient to the more efficient firms, and eventually the inefficient firms exit from the export market as they cease to sustain the highly competitive market. Stiff competition also forces exporters to cut costs by eliminating the source of managerial and organisational inefficiencies (Baldwin & Caves (1997), and Clerides et al (1998)).

From this brief review of the literature, this chapter contributes by examining whether industry level data support the country level findings. Capital intensity (the ratio of capital stock to employment) and average size (the ratio of real gross output to number of establishments in the industry) variables are included in the model as other possible variables that can influence both or either export or productivity, and directly or indirectly. This study finds there is a unidirectional causality from export to productivity. Even though productivity does not cause export, there is a possibility of an indirect causality through size, as productivity cause size and size, in turn cause export.

4.3 Empirical Framework and Methodology

The econometric methodology applied uses the error correction mechanism and causality. An error-correction model is a dynamic model in which the movement of the variables in any periods is related to the previous period's gap from their long run equilibrium. Before the error correction model is regressed, each variable is tested to see if it has unit roots. This is to first establish whether the variables are stationary or not. If they are non-stationary, their regression coefficients will be misleading. The order of integration of variables should be similar to each other to avoid problems of spurious correlation among them and to establish a linear combination among them. I apply two panel unit root tests based on Im, Pesaran and Shin (2003) and Choi (2001). If either of these tests provides evidence that the variables to be integrated of order 1 (I(1)), I proceed to test them for panel cointegration. Cointegration tests will identify whether exports and productivity share a common trend so that they can be considered to have a long-run equilibrium relationship which hold except for a stationary stochastic error, which allow for short-run deviations (Marin, 1992). To establish this long run equilibrium, I use Kao (1999) and Pedroni (1999) residual-based panel cointegration tests[3]. Due to the relatively short time span (T=19), a panel data environment would be the most appropriate to provide robust inference as long as the size of the panel is sufficiently large. However, it is essential to mention here that Kao tests perform better than Pedroni in samples that have small T (see Gutierrez, 2003). For comparison purpose, I use Pedroni tests to see if they provide consistent results with Kao tests. Even though I have a relatively short T, with 63 industries data available, the panel offers a total of 1197 observations. In this sense, information from different industries is utilised in addition to the time period spanned by each industry.

After confirming the long run or cointegration relationship, the short run relationship is estimated by constructing the error correction mechanism (ECM). I incorporate the effect of deviations from the long term contemporaneous relation in future changes in productivity and export in an error correction model. This effect of deviations is captured by the lagged error correction term in the ECM. If there is a short run relationship among the variables, the coefficient of the error correction term is expected to be consistently negative and significant. It also indicates that short term disequilibrium between productivity and export relationship tends to be corrected. In the cointegrating framework, the estimation of the error correction model and Granger causality tests allow me to verify the direction of causality in both the long run and the short run. Besides running Granger causality tests in the error correction models (Granger, 1988), they can also be performed within a VAR model.

In the error correction models, I use the Engle-Granger two-step procedure. In the first step, the long run models are estimated in equation 4.1 and 4.2. The

[3] It is not the scope of this chapter to address the issue of how many cointegrating vectors exist.

disequilibrium or error terms, u_{1it} from equation 4.1 and u_{2it} from equation 4.2 of the long run estimates are obtained in equations 4.1a and 4.2a respectively, as follows:

$$p_{it} = \gamma_t + \eta_i + \alpha_1 x_{it} + \alpha_2 k_{it} + \alpha_3 s_{it} + u_{1it} \qquad (4.1)$$

$$u_{1it} = p_{it} - \gamma_t - \eta_i - \alpha_1 x_{it} - \alpha_2 kl_{it} - \alpha_3 s_{it} \qquad (4.1a)$$

And

$$x_{it} = \gamma_t + \eta_i + \alpha_1 p_{it} + \alpha_2 k_{it} + \alpha_3 s_{it} + u_{2it} \qquad (4.2)$$

$$u_{2it} = x_{it} - \gamma_t - \eta_i - \alpha_1 p_{it} - \alpha_2 k_{it} - \alpha_3 s_{it} \qquad (4.2a)$$

p denotes the natural logarithm of labour productivity, γ_t is the time specific effect, η_i is the individual effect, *x* is the real exports in natural logarithm, *k* is the ratio of capital stock to the number of labours, *s* is the average size of industries at four-digit level, *u* is the error term, and α is the coefficient of the respective variables. Subscripts *i* and *t* represent the 63 individual industries and 19 years, from 1981 to 1999, respectively.

In the second step, the variables are transformed to first difference, and the error terms, denoted as u_{1it} and u_{2it}, are lagged one period. The models are specified as follows:

$$\Delta p_{it} = \alpha_{1i} + \delta_1 t + \beta_{11}\Delta x_{it} + \beta_{12}\Delta k_{it} + \beta_{13}\Delta s_{it} + \lambda_1 u_{1it-1} + \upsilon_{1it} \qquad (4.3)$$

$$\Delta x_{it} = \alpha_{2i} + \delta_2 t + \beta_{21}\Delta p_{it} + \beta_{22}\Delta k_{it} + \beta_{23}\Delta s_{it} + \lambda_2 u_{2it-1} + \upsilon_{2it} \qquad (4.4)$$

where υ is the random disturbance. To establish causality, either Δp_{it} or Δx_{it} (or both) must be caused by z_{it-1}, which is itself a function of p_{it-1} and x_{it-1}, respectively. This causality indicates the long run and short-run forecastibility of one variable given that another variable changes. The variable, z_{it-1}, represents how far the variables are from the equilibrium relationship and its coefficient, λ, estimates how this short run variables adjust towards equilibrium in order to keep the long run relationship sustainable (Canning & Pedroni, 1999). Even though these ECM models present causality between the variables, I check whether my results in the ECM models are robust to the Granger multivariate causality models. In addition, Granger bivariate causality models are also used to provide different information as two variables are observed at a time.

In Granger causality, the null hypothesis assumes there is strong exogeneity in the variables, which is sometimes called as Granger noncausality. This hypothesis assume that the lagged values of the right-hand side variables do not provide information about the conditional mean of the left-hand side variable, once lagged values of the left-hand side variable, itself, are accounted for. Tests of the restrictions are based on simple F tests in the single equations of the VAR model. Export is said to Granger cause productivity if we are better able to predict productivity using all available information than if we use all the information apart from export. To calculate for the F statistics, I differenced the residual sum of squares of a restricted equation (excluding the lags of exports growth variable on the right hand side of the equation) with the residual sum of squares of an unrestricted equation (which includes the lags of exports growth variable on the right hand side of the equation). If the calculated F-statistics is more than the critical F statistics, thereby I can establish the significance of the causality between two and more variables. The Granger multivariate causality models are specified below:

$$p_{it} = \sum_{j=1}^{p} \beta_{11j} p_{i(t-j)} + \sum_{d=1}^{q} \beta_{12d} x_{i(t-d)} + \sum_{d=1}^{q} \beta_{13d} k_{i(t-d)} + \sum_{d=1}^{q} \beta_{14d} s_{i(t-d)} + u_{1it} \quad (4.5)$$

$$x_{it} = \sum_{j=1}^{p} \beta_{21j} x_{i(t-j)} + \sum_{d=1}^{q} \beta_{22d} p_{i(t-d)} + \sum_{d=1}^{q} \beta_{23d} k_{i(t-d)} + \sum_{d=1}^{q} \beta_{24d} s_{i(t-d)} + u_{2it} \quad (4.6)$$

Equation 4.5 postulates that the current labour productivity growth is related to the past values of the labour productivity growth itself as well as of exports growth, and equation 4.6 postulates an analogous behaviour for exports.

I then carry out tests which show whether movements in exports help predict movements in productivity. A bivariate Granger (1969) causality testing procedure is performed to determine the direction of causality between any pair of the export, capital intensity, size and labour productivity variables. The bivariate models are specified below:

$$y_{it} = \alpha_{10} + \alpha_{11} y_{it-1} + \ldots + \alpha_{1l} y_{it-l} + \beta_{11} x_{it-1} + \ldots + \beta_{1l} x_{it-l} + \varepsilon_{1it} \quad (4.7)$$

$$x_{it} = \alpha_{20} + \alpha_{21} x_{it-1} + \ldots + \alpha_{2l} x_{it-l} + \beta_{21} y_{it-1} + \ldots + \beta_{2l} y_{it-l} + \varepsilon_{2it} \quad (4.8)$$

Bivariate regressions using equations (4.7)[4] and (4.8) are applied for all possible pairs of (x,y) series in the panel. The reported F-statistics are the Wald statistics for the joint hypothesis:

$$\beta_1 = \beta_2 = \ldots = \beta_l = 0 \quad (4.9)$$

The null hypothesis is that x does not Granger cause y in equation (4.7) and that y does not Granger cause x in equation (4.8). With these tests, I capture the possibility of indirect causality of exports and productivity.

[4] The l in both equations (4.7) and (4.8) represents the lag length. The maximum lag used corresponds to the longest time over which one of the variables could help predict the other, considering the time period covered in the study.

4.4 Data Description

I use the Malaysian data obtained from the United Nations Industrial Development Organisation (UNIDO) dataset. The data covers 19 years, from 1981 to 1999 and 63 manufacturing industries. Out of the initial 73 industries, 10 industries are excluded due to limited data on exports. Other minor missing data are imputed based on the exponential growth of the available data in each particular industry.

Labour productivity, *P*, is defined as the real gross output (in US$) divided by the number of employees. Exports, *X*, is real exports (in US$). Capital intensity, *K*, is defined as the ratio of the industry's capital stock to the number of employees. Capital stock is generated from real gross fixed capital formation using the inventory perpetual method. Size, *S*, is defined as the industry's average annual sales turnover, which is derived from the ratio of real gross output to the number of establishments in the individual industry. All variables are transformed into natural logarithm.
Table 1 show the descriptive statistics of all the variables that I use in my regression. The 63 manufacturing industries from the period 1981 to 1999 give a total observation of 1197. The statistics below are in actual units for these remaining industries.

**** Insert Table 4.1 here ****

P represents labour productivity, *K* is capital intensity, *S* is average size per establishment and *X* is real exports in US$. From Table 1, it is evident that there is high standard deviation in the data for all variables. This is influenced by the nature of the industries within each category that is either capital intensive or labour intensive. As a panel, the statistics capture the standard deviation of the data from the time and cross industries dimension.

The correlation among these variables (in natural logarithm) is shown in Table 4.2. All of them seem to be significantly correlated with labour productivity, with size, *ln s*, to be particularly highly correlated to labour productivity compared to capital intensity, *ln k*, and exports, *ln x*.

**** Insert Table 4.2 here ****

4.5 Results and Discussion

4.5.1 Panel Unit Roots

Before I can establish causality between the variables, I have to test if there is any problem of spurious correlation. Spurious correlation is said to occur when the errors of different periods are correlated due the nonstationarity of the data. Hence, the variance of errors is not consistently estimated and the standard t-statistic is wrongly calculated. This problem is common in time series data. To detect this problem, panel unit root tests are performed to identify the nonstationarity of the data or the presence of a unit root. For this purpose, Im, Pesaran and Shin (2003) (IPS) and Phillips-Perron-Choi (2001) (PPC) tests are used. These two tests are described in Appendix A. Both have a null hypothesis of unit roots and use the Schwarz Information Criterion. In addition, PPC apply Newey-West bandwidth selection and Bartlett kernel. I assume individual effects and individual linear trends as exogenous variables.

**** Insert Table 4.3 here ****

I estimate the random walk regressions by using predetermined (at lag=3) (Table 4.3) and the optimum lags for each industry that range between 0 and 3 (Table 4.4), and run the IPS and PPC tests to identify the presence of a unit root. The regressions that use optimum lags offer more observations and improve the performance of the regressions compared to those that use predetermined (fixed) lags. Hence, I use the results with the optimum lags applied in the regressions. The results are reported in Table 4.4. Both IPS and PPC tests suggest that real exports, labour productivity and size are integrated of order 1. Besides that, PPC find capital intensity to be I(1). Other variables are I(0) in both tests. Variables with I(1), i.e. real exports, labour productivity, size and capital intensity, fulfilled the requirement for the following cointegration tests.

**** Insert Table 4.4 here ****

4.5.2 Panel Cointegration

Kao (1999) and Pedroni (1999) tests are residual-based. These tests procedures are explained in Appendix B. Following Kao et al (1999), OLS with bias-correction and dynamic OLS are used to generate the residuals. Kao (1999) assume the coefficients to be common across all industries whereas Pedroni (1999) tests allow for heterogeneity for each individual industry. This provides evidences from 2 groups of tests that consider different assumptions. Kao (1999) presents 2 types of panel cointegration tests, the Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) types. Pedroni (1999) provides seven pooled Phillips and Perron-type tests. The first four test statistics are based on pooling along the within-dimension (panel statistics). The last three test statistics are based on pooling along the between-dimension (group mean statistics). Both tests have a null hypothesis of no cointegration. Table 4.5 shows the results using the OLS with bias correction with labour productivity as the dependent variable. The Kao DF tests are based on a simple OLS regression of $\hat{e}_{it}$ on its own lagged value. Correction for serial correlation was made on the OLS and t-statistics.

**** Insert Table 4.5 here ****

Table 4.6 shows the results using the dynamic OLS. Most test statistics are significant so that the null of no cointegration is mainly rejected. Therefore, the cointegration relationship among variables for all equations is supported.

**** Insert Table 4.6 here ****

As I am regressing for error correction and causality models, I further perform similar tests on regressions that have exports as their dependent variable. When I perform Kao cointegration tests on exports, generally, all regressions (in Table 4.7) cannot reject the null hypothesis of no cointegration for the DF_ρ, DF_t, and ADF tests. On the other hand, Pedroni tests reject the null of no cointegration. As I mentioned earlier, Kao tests are more powerful than Pedroni tests for a small sample (Gutierrez, 2003). On this basis, Kao tests results are more reliable than Pedroni. As Gutierrez (2003) notes, Pedroni tests do not perform well in samples where T is small[5].

**** Insert Table 4.7 here ****

**** Insert Table 4.8 here ****

4.5.3 Error Correction Model

After confirming that the variables are cointegrated, the error term is generated from the long run equation as in equation 4.1a and 4.2a. The results from the

[5] Nevertheless, an important point can be made on this outcome, i.e. if an analyst is not aware of the performance of these test statistics, he can easily make wrong conclusions on the cointegration properties of variables. This may lead to further incorrect interpretation of the results in the ECM.

error-correction models are shown below. Due to the significant impact of the Asian financial crisis on Malaysia's economic performance, we include a dummy to represent the years between 1997 and 1999 when it occurred.

**** Insert Table 4.9 here ****

I hypothesise that if export activities drive the industries to improve their productivity and competitiveness, due to greater competitive pressures, then there exists a long term contemporaneous relationship between export and labour productivity. Such a relation suggests that export and labour productivity are cointegrated. Based on the Granger representation theorem (Engle and Granger, 1987), my analysis of the change in labour productivity over time must incorporate an error correction term to show the effect of deviations from long term contemporaneous relationship on future labour productivity changes.

**** Insert Table 4.10 here ****

The lagged error correction term in Table 4.9 is consistently negative and significant, indicating that the short term disequilibrium between exports and labour productivity tends to be corrected. According to Granger, this will prove at least unidirectional causality between the variables regressed. Similarly, when exports are regressed as the dependent variable, its lagged error correction term is consistently negative and significant, indicating that the short term disequilibrium between export and labour productivity growth also tend to be corrected. Labour productivity is significant at 1% significance level for all panels in Table 4.10. However, most of the other regressors in Table 4.10 are not significant as compared to those in Table 4.9. This means that these other regressors are mostly not important in determining exports in the short run. From these ECM results, it is evident that there is a bidirectional causality between exports and labour productivity.

4.5.4 Granger Causality

The Granger multivariate causality results support the ECM results, i.e. past exports have Granger causality and predictive effects on current labour productivity, and vice versa. However, the Granger bivariate causality tests show evidence of unidirectional causality that runs from exports to productivity. Following Davidson and MacKinnon, I further conduct tests for Granger causality with additional lags[6] of the right hand side variables. See Table 4.11. Except for when lagged one and two periods, the results show unidirectional causality, where the past exports have Granger causality effects on the current labour productivity, not vice versa. In the bivariate model, the co-existence of other factors, like size and capital intensity, and their importance in having a simultaneous impact on exports have been ignored. In this sense, a multivariate model is more reliable in giving a better picture in explaining the causality between exports and productivity.

**** Insert Table 4.11 here ****

The results from the multivariate models provide evidence that, besides increasing their productivity before exporting, the industries continue to increase their productivity after exporting to sustain in the export market. The industries prepare themselves to be more competitive and productive before entering the export market because they are aware that they cannot compete if they continue to produce the way they were. Even after exporting, the competition continues. In order to sustain in the export market, these exporting industries have to allocate their resources more efficiently, and learn from other firms that adopt the best practice technology, to make them self even more productive and competitive in the export market. There is a clear evidence of

[6] Considering there are only 18 years of t, we use a maximum of 8 lags.

'learning-by-exporting' process for all the observations. I further tested for robustness of my results by dividing the data into 6 different levels of export-intensity (export/output). The results are robust for most of the 6 levels of export intensity.

**** Insert Table 4.12 here ****

Besides having a bidirectional causality, exports and productivity also have indirect causalities between them through size and capital intensity. As both exports and productivity have a bidirectional causality with size and capital intensity (see Table 4.11), there is a possibility if indirect causalities between export and productivity through them.

4.6 Conclusions

This chapter re-examines the direction of the causality between export and productivity growth for Malaysian 63 manufacturing industries. By using ECM and Granger causality tests, I find that these industries have a bidirectional causality between them. This causality confirms the export-led growth and growth-driven export hypotheses in the case of Malaysia manufacturing industries.

My results provide evidence that export growth and labour productivity growth have long run equilibrium. Short run disequilibrium tends to be corrected, so that eventually, they are in equilibrium in the long run. In the error correction model, export growth determines labour productivity growth in the short run, and it tends to correct any disequilibrium to establish a long run relationship. Similarly, labour productivity growth also determines export growth in the short run and tends to correct its disequilibrium in the long run. This means, labour productivity growth does determine export in the long run. The Granger causality tests support the error correction model results.

This study addresses the question of whether the association between export and productivity reflects causation flowing from export experience to improvements in labour productivity only or there is a reverse flow as well. It confirms the bidirectional causality between exports and labour productivity, and adds that there are possibilites of indirect causalities between them through size and capital intensity.

TABLES AND FIGURES

Table 4.1: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Maximum
P	65,149.57	155,686.9	2,809.523	2,736,445
K	7,138.606	17,399.96	52.885	365,630.9
S	8,611,932	2.63e+07	28,792.49	3.23e+08
X	1,042,676	1.56e+07	41.076	4.72e+08

Table 4.2: Correlation Matrix

	ln p	***ln k***	***ln s***	***ln x***
ln p	1.0000			
ln k	0.4405	1.0000		
ln s	0.8005	0.3368	1.0000	
ln x	0.2559	-0.0828	0.3720	1.0000

Table 4.3: Panel Unit Roots Tests Using Fixed Lag

Variables	Im, Pesaran and Shin[#]		Phillips Perron-Choi[~]	
	Level	**Difference**	**Level**	**Difference**
lnx	2.0087	-1.9710	1.2907	-16.6864
	(0.9777)	(0.0244)*	(0.9016)	(0.000)*
lnx-l	1.1680	-5.4238	-2.4308	-20.7964
	(0.8786)	(0.000)*	(0.0075)*	(0.000)
lnk	1.9279	-2.8361	-6.9204	-25.8848
	(0.973)	(0.0023)*	(0.000)*	(0.000)
lnk-l	2.1902	-1.0750	-0.5973	-17.0865
	(0.9857)	(0.1412)	(0.2751)	(0.000)*
lnq-l	3.6676	2.4251	5.7708	-15.3761
	(0.9999)	(0.9923)	(1.000)	(0.000)*
lnl	-0.7383	1.06802	-1.7538	-14.4665
	(0.2301)	(0.8572)	(0.0397)*	(0.000)
lns	9.1736	-2.0402	0.9808	-21.3131
	(1.000)	(0.0207)*	(0.8367)	(0.000)*

Notes:
(1) # W-stat
(2) ~ Z-stat
*(3) * cannot reject the null hypothesis of unit roots*
(4) P-values in parentheses
(5) At levels, total observations = 945, at first difference = 882
(6) Lags are set to 3.

Table 4.4: Panel Unit Roots Tests Using Optimum Lags and Bandwidth

Variables	Im, Pesaran and Shin[#]		Phillip-Peron-Choi[~]	
	Level	Difference	Level	Difference
lnx	1.009 (0.8435)	-18.6545 (0.000)*	1.2907 (0.9016)	-16.6864 (0.000)*
lnx-l	-2.9026 (0.0019)*	-22.6514 (0.000)	-2.4308 (0.0075)*	-20.7964 (0.000)
lnk	-5.9738 (0.000)*	-33.7705 (0.000)	-6.9204 (0.000)*	-25.8848 (0.000)
lnk-l	-1.7032 (0.0443)*	-15.192 (0.000)	-0.5973 (0.2751)	-17.0865 (0.000)*
lnq-l	1.24485 (0.8934)	-12.7922 (0.000)*	5.7708 (1.000)	-15.3761 (0.000)*
lnl	-3.5666 (0.0002)*	-11.2233 (0.000)	-1.7538 (0.0397)*	-14.4665 (0.000)
lns	-0.4302 (0.3335)	-22.6552 (0.000)*	0.9808 (0.8367)	-21.3131 (0.000)*

Notes:
(1) # W-stat
(2) ~ Z-stat
*(3) * cannot reject the null hypothesis of unit roots*
(4) P-values in parentheses

Table 4.5: Panel Cointegration Tests Using Bias-Corrected Fixed Effects
Dependent Variable: Labour Productivity

Variable	(1)	(2)	(3)	(4)
ln x	0.0712 (7.2713)**	0.1264 (10.5539)**	0.0720 (7.2704) **	
ln x-l				0.0833 (7.6668) **
ln k	0.0122 (1.1670)	0.0358 (2.7324) **		0.0123 (1.1819)
ln k^r			-0.0187 (-0.9981)	
ln s	0.3112 (20.4155)**		0.3252 (20.1039) **	0.3312 (22.0973) **
R-square	0.4966	0.2491	0.4982	0.4956
Kao DF (1999) Tests				
DF_ρ	-9.2119 (0.000) **	-9.1034 (0.000) **	-9.3457 (0.000) **	-8.9739 (0.000) **
DF_t	-7.0227 (0.000) **	-6.8457 (0.000) **	-7.1776 (0.000) **	-6.9114 (0.000) **
DF_ρ^*	-21.5630 (0.000) **	-22.1290 (0.000) **	-22.1606 (0.000) **	-21.0829 (0.000) **
DF_t^*	-8.4099 (0.000) **	-8.2068 (0.000) **	-8.4908 (0.000) **	-8.3335 (0.000) **
Kao ADF test	-6.7726 (0.000) **	-7.5473 (0.000) **	-6.6526 (0.000) **	-6.4597 (0.000) **
Pedroni (1999) Tests				
Panel *v*-statistic	27.2146 (0.000) **	43.9961 (0.0000) **	29.5495 (0.000) **	25.9588 (0.000) **
Panel ρ -statistic	-53.7861 (0.000) **	-44.2130 (0.0000) **	-50.1062 (0.000) **	-55.2100 (0.000) **
Panel *t*-statistic (non-parametric)	-16.3944 (0.000) **	-14.6272 (0.0034) **	-15.8226 (0.000) **	-16.5937 (0.000) **
Panel *t*-statistic (parametric)	-172.2029 (0.000) **	-110.0687 (0.0000) **	-158.5916 (0.000) **	-183.0388 (0.000) **
Group ρ -statistic	-60.89723 (0.000) **	-53.4167 (0.0000) **	-63.1482 (0.000) **	-61.1485 (0.000) **
Group *t*-statistic (non-parametric)	-17.6771 (0.000) **	-15.9156 (0.0000) **	-18.0926 (0.000) **	-17.8273 (0.000) **
Group *t*-statistic (parametric)	-20.0852 (0.0010) **	-18.9984 (0.2742)	-20.6232 (0.0088) **	-20.1539 (0.0014) **

Notes:

(1) x-l is export/labour and k^r is real capital stock respectively.
(2) The bias-corrected t-ratio are reported in parentheses for each variable.
(3) P-values are reported in parentheses for Kao and Pedroni tests.
*(4) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*
(5) All regressions include unreported, industry-specific constants.

Table 4.6: Panel Cointegration Tests Using Dynamic OLS
Dependent Variable: Labour Productivity

Variable	(1)	(2)	(3)	(4)
ln x	-0.0170 (-1.3667)	0.1315 (8.6731) **	-0.0516 (-4.1073) **	
ln x-l				0.0296 (2.1483)*
ln k	0.1500 (11.2991) **	0.3742 (22.5251) **		0.1536 (11.6164) **
ln k^r			-0.0628 (-2.6462) **	
ln s	0.5048 (26.1451) **		0.6171 (30.1174) **	0.4828 (25.4317) **
Kao DF (1999) Tests				
DF_ρ	-6.5834 (0.000) **	-9.8017 (0.000) **	-6.4700 (0.000) **	-7.7814 (0.000) **
DF_t	-4.1562 (0.000) **	-7.5888 (0.000) **	-4.0348 (0.000) **	-5.6105 (0.000) **
DF^*_ρ	-16.8651 (0.000) **	-23.7422 (0.000) **	-17.1608 (0.000) **	-19.2755 (0.000) **
DF^*_t	-6.2217 (0.000) **	-8.6871 (0.000) **	-6.1359 (0.000) **	-7.3371 (0.000) **
Kao ADF test	-3.5051 (0.0002) **	-6.6288 (0.000) **	-3.5744 (0.0002) **	-4.2620 (0.000) **
Pedroni (1999) Tests				
Panel v-statistic	16.3495 (0.000) **	17.0321 (0.000) **	15.6669 (0.000) **	18.2804 (0.000) **
Panel ρ -statistic	-59.9761 (0.000) **	-57.9341 (0.3554)	-52.8349 (0.000)	-64.3122 (0.000)
Panel t-statistic (non-parametric)	-16.3201 (0.000) **	-16.9155 (0.3554)	-15.3110 (0.000) **	-17.4467 (0.0009) **
Panel t-statistic (parametric)	-186.7461 (0.000) **	-148.7350 (0.000) **	-167.1246 (0.000) **	-198.1556 (0.000) **
Group ρ -statistic	-64.9214 (0.000) **	-67.5946 (0.000) **	-66.4763 (0.000) **	-69.9191 (0.000) **
Group t-statistic (non-parametric)	-17.4398 (0.000) **	-18.4806 (0.1040) **	-17.4921 (0.000) **	-18.7778 (0.000) **
Group t-statistic (parametric)	-18.3563 (0.000) **	-20.0774 (0.2198)	-20.3591 (0.0032) **	-19.8363 (0.0003) **

Notes:
(1) x-l is export/labour and k^r *is real capital stock.*
(2) t-ratio in parentheses for each variable
(3) P-values in parentheses for Kao and Pedroni tests
*(4) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*
(5) All regressions include unreported, industry-specific constants.

Table 4.7: Panel Cointegration Tests Using Bias-Corrected Fixed Effects
Dependent Variable: Exports

Variable	(1)	(2)	(3)	(4)
ln p	1.7405	2.3936	1.7108	1.7077
	(8.9322)	(13.9996)	(8.8288)	(8.7645)
ln k	-0.0875	-0.0692		
	(-1.6266)	(-1.1689)		
ln k^r			0.1869	
			(1.9757)	
ln s	0.5307		0.4093	0.5208
	(5.6526)		(4.1538)	(5.5209)
R-square	0.2498	0.2397	0.2585	0.2497
Kao DF (1999) Tests				
DF_ρ	-0.6751	-1.2783	-0.8601	-0.6537
	(0.2498)	(0.1006)	(0.1949)	(0.2567)
DF_t	-0.1171	-0.9109	-0.3714	-0.0780
	(0.4534)	(0.1812)	(0.3552)	(0.4689)
DF^*_ρ	-9.3358	-11.1642	-9.7422	-9.3625
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DF^*_t	-3.3417	-3.9417	-3.5310	-3.3217
	(0.0004)	(0.0000)	(0.0002)	(0.0004)
Kao ADF test	-1.5482	-2.2783	-1.3769	-1.5183
	(0.0608)	(0.0114)	(0.0843)	(0.0645)
Pedroni (1999) Tests				
Panel v-statistic	40.0907	44.1986	36.4580	41.9282
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel ρ-statistic	-38.4695	-40.1174	-37.5218	-36.0179
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Panel t-statistic (non-parametric)	-12.7924	-13.8349	-12.6789	-12.1873
	(0.0000)	(0.0002)	(0.0000)	(0.0000)
Panel t-statistic (parametric)	-28.9965	-30.5348	-30.3049	-26.4113
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group ρ-statistic	-41.8948	-44.9877	-45.7827	-41.8187
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group t-statistic (non-parametric)	-12.1102	-13.8830	-12.9696	-12.0286
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Group t-statistic (parametric)	-13.2465	-15.2694	-14.5891	-13.1328
	(0.0000)	(0.0000)	(0.0000)	(0.0000)

Notes:
(1) The bias-corrected t-ratio are reported in parentheses for each variable.
(2) P-values are reported in parentheses for Kao and Pedroni tests.
*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*
(4) All regressions include unreported, industry-specific constants.

Table 4.8: Panel Cointegration Tests Using Dynamic OLS
Dependent Variable: Exports

Variable	(1)	(2)	(3)	(4)
ln p	-0.2449	0.7691	-0.5831	-0.4939
	(-0.9921)	(3.5514)**	(-2.3757) **	(-2.0011)**
ln k	-0.3792	-0.4267		
	(-5.5656)**	(-5.6917)**		
ln k^r			-0.4352	
			(-3.6328)**	
ln s	0.8070		1.1624	0.8253
	(6.7864)**		(9.3125)**	(6.9071)**
R-square	0.3058	0.1242	0.2834	0.2504
Kao DF (1999) Tests				
DF_ρ	1.1065	0.1861	2.4612	2.5105
	(0.1343)	(0.4262)	(0.0069)**	(0.0060 **
DF_t	2.3066	1.0772	4.1634	4.2335
	(0.0105)*	(0.1407)	(0.0000)**	(0.0000)**
DF^*_ρ	-6.2806	-9.0776	-3.9971	-3.8880
	(0.0000)**	(0.0000)**	(0.0000)**	(0.0001)**
DF^*_t	-1.6031	-2.6822	-0.2556	-0.1930
	(0.0545)	(0.0037)**	(0.3991)	(0.4235)
Kao ADF test	-1.5893	-2.9416	-0.3772	-0.1768
	(0.0560)	(0.0016)**	(0.3530)	(0.4298)
Pedroni (1999) Tests				
Panel v-statistic	18.4107	22.7948	17.7891	24.5634
	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Panel ρ -statistic	-26.4571	-26.3903	-22.8432	-20.0189
	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Panel t-statistic	-10.3751	-11.0320	-8.5327	-8.0553
(non-parametric)	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Panel t-statistic	-25.7964	-24.9163	-17.9837	-15.7487
(parametric)	(0.0000)**	(0.0000)**	(0.0051)**	(0.0595)
Group ρ -statistic	-32.2467	-30.9856	-29.9323	-24.1707
	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Group t-statistic	-11.3835	-12.3331	-9.4377	-8.8569
(non-parametric)	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**
Group t-statistic	-11.9986	-12.9104	-10.2207	-9.0517
(parametric)	(0.0000)**	(0.0000)**	(0.0000)**	(0.0000)**

Notes:

(1) t-ratio in parentheses for each variable

(2) P-values in parentheses for Kao and Pedroni tests

*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*

(4) All regressions include unreported, industry-specific constants.

Table 4.9: Error-correction Model
Dependent Variable: Labour Productivity Growth

Variables	(1)	(2)	(3)	(4)	(5)
Constant	-0.0029 (0.0053)	0.0068 (0.0064)	-0.0038 (0.0053)	0.0077 (0.0059)	0.0040 (0.0057)
$\Delta \ln x$	0.0251 (0.0097)**	0.0510 (0.0118)**	0.0239 (0.0098)*	0.0212 (0.0098)*	
$\Delta \ln x\text{-}l$					0.0481 (0.0090) **
$\Delta \ln k$	0.0283 (0.0069) **	0.0415 (0.0085)**		0.0237 (0.0070)**	
$\Delta \ln k^r$					-0.0804 (0.0142) **
D9799				-0.0580 (0.0145)**	-0.0578 (0.0141) **
$\Delta \ln s$	0.3330 (0.0141) **		0.3382 (0.0142)**	0.3193 (0.0145)**	0.3448 (0.0151) **
Z_{t-1}	-0.0733 (0.0099) **	-0.0501 (0.0081)**	-0.0680 (0.0095)**	-0.0004 (0.0001)**	-0.0638 (0.0099) **
R^2: within	0.3899	0.0947	0.3806	0.3939	0.4144
between	0.1518	0.0324	0.1453	0.1633	0.1776
overall	0.3699	0.0604	0.3610	0.387	0.3992
Wald χ^2 (P value)	662.77 (0.000)	72.58 (0.000)	638.36 (0.000)	687.434 (0.000)	749.61 (0.000)
Observations	1134	1134	1134	1134	1134

Notes:
(1) x-l and k^r are exports/labour and real capital stock respectively.
(2) Time dummies are included in the panel but not reported.
*(3) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% respectively.*
(4) Values in parentheses are standard errors except for wald chi-square test which shows the p-value.

Table 4.10: Error-correction Model
Dependent Variable: Export Growth

Variables	(1)	(2)	(3)	(4)	(5)#
Constant	0.1431 (0.0153)	0.1445 (0.0153)	0.1440 (0.0153)	0.1565 (0.0173)	0.0993 (0.0179)
$\Delta\, ln\, p$	0.2770 (0.0866)**	0.3123 (0.0713)**	0.2601 (0.0862)**	0.2514 (0.0879)**	0.5423 (0.0919)**
$\Delta\, ln\, k$	-0.0321 (0.0210)	-0.0300 (0.0210)		-0.0361 (0.0211)	
$\Delta\, ln\, k^r$					0.1911 (0.0455)**
D9799				-0.0759 (0.0450)	0.0362 (0.0465)
$\Delta\, ln\, s$	0.0231 (0.0515)		0.0203 (0.0516)	0.0145 (0.0518)	-0.1208 (0.0575)*
Z_{t-1}	-0.0534 (0.0083)**	-0.0468 (0.0079)**	-0.0519 (0.0081)**	-0.0493 (0.00865)**	-0.0591 (0.0089)**
R^2: within	0.0764	0.0674	0.0761	0.0725	0.1014
between	0.0240	0.0242	0.0303	0.0240	0.0374
overall	0.0521	0.0463	0.0510	0.0545	0.08069
Wald χ^2 (P value)	62.02 (0.000)	54.92 (0.000)	60.69 (0.000)	64.97 (0.000)	98.95 (0.000)
Observations	1134	1134	1134	1134	1134

Notes:
(1) k^r is real capital stock.
*(2) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% levels, respectively.*
(3) Values in parentheses are standard errors.
(4) # The dependent variable is export/labour growth.

Table 4.11:
Bivariate Causality tests at Different Lags

Null Hypothesis	t-1	t-2	t-4	t-6	t-8
$\ln p$ does not cause $\ln x$	0.5779~	1.8497	2.0125	1.5681	1.0904
$\ln x$ does not cause $\ln p$	1.2149	1.1390	4.5895**	4.1373**	3.6024**
$\ln p$ does not cause $\ln k$	20.0083**	7.5128**	3.7834**	5.2705**	4.7554**
$\ln k$ does not cause $\ln p$	5.6010*	3.0880*	1.2270	2.4689*	2.8126**
$\ln p$ does not cause $\ln s$	0.2508	4.8096**	7.5533**	6.0789**	3.5646**
$\ln s$ does not cause $\ln p$	9.1268**	5.7785**	6.5340**	12.5491**	9.2650**
$\ln x$ does not cause $\ln k$	1.0518	5.0578**	2.5749*	1.9172	1.0997
$\ln k$ does not cause $\ln x$	0.1896	0.1340	0.2042	3.6822**	3.0268**
$\ln x$ does not cause $\ln s$	12.4896**	6.8030**	4.4290**	3.7080**	3.8319**
$\ln s$ does not cause $\ln x$	1.6791	0.58716	2.7977*	4.8663**	3.1884**
$\ln s$ does not cause $\ln k$	16.2226**	6.8902**	5.1480*	6.3917**	5.9837**
$\ln k$ does not cause $\ln s$	9.6490**	3.3819*	4.4936**	5.5626**	4.7724**
Critical F at 1%	6.63	4.61	3.32	2.80	2.51
5%	3.84	3.00	2.37	2.10	1.94
No of observation	1071	1008	882	756	630

Note :
(1) ~ F-statistics
*(2) Coefficients are labelled ** and * to denote statistical significance at 1% and 5% levels, respectively.*

Table 4.12:
Multivariate Causality Tests at Different Lags

Null Hypothesis	t-1	t-2	t-4	t-6	t-8
$\ln p$ does not cause $\ln x$	7.3241**	6.5678**	4.2099**	3.4913**	2.7686**
$\ln x$ does not cause $\ln p$	2.7752	1.2422	3.6698**	2.5771*	2.3834*
Critical F at 1%	6.63	4.61	3.32	2.80	2.51
5%	3.84	3.00	2.37	2.10	1.94
No of observation	1071	1008	882	756	630

Note :
(1) ~ F-statistics
(2) *Coefficients are labelled ** and * to denote statistical significance at 1% and 5% level.*

CONCLUSIONS

5.1 Introduction

This final chapter summarises the major findings and policy implications that can be derived from the empirical findings in the earlier chapters. It is organised as follows: I begin by providing a general review and findings of the three empirical chapters in this dissertation. Next I point to the policy implications that have direct impact on the outcome of the results, which emerge from the analyses that I perform. Lastly, due to the limitations of the studies that I have performed, I recommend areas for further work to follow up on what this dissertation and other current work has done.

5.2 General Review and Findings of the Study

The fundamental questions examined by this dissertation concern size, capital intensity, exports and R&D as determinants of productivity in the manufacturing sector. More specifically, this dissertation streamlines three issues: (i) the determinants of productivity from the perspectives of size, taking into account the different proxies use to describe size; (ii) the effect of research and development (R&D) on total factor productivity, taking into consideration its different sources; and (iii) the causality of exports on productivity, or vice versa. I have formulated empirical models and tested the above issues by using panel data that covers all industries in the manufacturing sector of which data are available for analysis. Before conducting the empirical studies to investigate the above issues, I survey both theoretical and empirical developments in the first section of Chapters Two to Four. The analyses are primarily reported in Chapters Two to Four of the dissertation.

Chapter Two looks into how the average size, measured by annual sales turnover, of firms in an industry may affect the growth or performance of 73 industries at 4-digit ISIC level, from 1980-1999 for Malaysia. I apply Solow growth model, as used by Mankiw, Romer and Weil (1992), adapted to our industry level data. As in their model, labour productivity of a country is the dependent variable but in my model I use it as an indicator of the industry performance. In general, the empirical studies indicate that size and productivity nexus is positive and significant, taking into account in this case other factors like economic performance, capital intensity, exports and intermediate materials and services. The empirical findings also demonstrate that the role of size in promoting productivity growth of industries is important. From the three proxies of size, namely paid-up capital, annual sales turnover and number of employment, it is evident that only annual sales turnover manage to capture the consistently increasing pattern of productivity growth as size increases for all the three size groups: small, medium and large. This result confirms the Verdoorn's Law which states that the growth of production is closely related to labour productivity. In the same way, this suggests that the mean (labour productivity) growth rate of firms declines with size, and in line with other works by Hall (1987), Evans (1987) and Farinas and Moreno (2000). Annual sales turnover provides us with unbiased results because it does not favour either capital or labour intensive industries. Further, it provides us with more reliable evidence that is consistent to the theory of the marginal productivity of labour.

Chapter Two also detects a significant cyclical pattern for the whole panel at level, which may imply a negative growth in the industry affects the labour productivity in a negative way. My results indicate that there is an important role played by capital intensity (capital-labour ratio) and intermediate material in determining labour productivity. This requires investment in appropriate technology, and good quality materials to be in place, in order to provide the impetus for sustainable industry performance. In checking for the stability of my results over four 5-years periods, many of the subperiods support the estimates of the overall period, with the main exception of the economic performance dummy, D, for all panels. I find only one can capture the economic performance effect. Size, capital-labour ratio, intermediate material and labour growth mostly show significant coefficients, both at level and first difference, except for some periods. In the identifying the significance of the fixed effects of each of the 14 industries that I include in the model, petroleum refinery industry is the major contributor to labour productivity, with its labour productivity 1.61% higher than the rest at 1% significance level. This is probably due to the fact that it is a very capital-intensive industry. This is followed by industrial chemicals industry, significant at 1% level, and 'other chemicals' (D352) significant at 10% level.

In Chapter Three, I set to examine whether R&D and TFP have a long run relationship. Before examining for their long run relationship, I tested for unit root to identify the problem of spurious regression. Different procedures are applied for the unit root tests to see whether they indicate consistent results. I find the tests show consistent results for most tests. This means that all the tests either accept or reject the null hypothesis in all the tests, except for foreign R&D. The unit root tests confirm that TFP, LP, VA, the industry own R&D capital stock and other domestic industry R&D stock are integrated of order 1, whereas foreign R&D is integrated of order 0. To be cointegrated, the variables have to be stationary to avoid spurious regressions. Following this, I initially perform cointegration tests without the foreign R&D, and later include it to examine the effect. I find the residuals from both regressions to be cointegrated. This confirms that r and y relationship is sustainable in the long run.

After I examine the long run relationship between R&D and productivity, I then analyse the elasticities of each source of R&D capital stock on the industries productivity. The industry own R&D capital stock, r^o, in general, work in a negative way towards TFP, LP and VA of the industry. Cameron (2006) also shows negative coefficients for R&D capital for his UK sectoral TFP regressions. However, he did not address the issue of the negative R&D coefficients. My results indicate that the industries are benefiting from R&D spillovers from other domestic industries and foreign countries, but not from their own R&D capital stock. This is probably due to the high usage or contents of materials that are sourced from other industries and imported from other countries. Therefore, the individual industry benefit from other industries R&D. Domestic and foreign R&D and productivity prove to have long run equilibrium.

In Chapter Four, I re-examine the causality between productivity and exports in the case of Malaysian manufacturing industries for the period of 1980-1999. Analysing the direction of causality of export and productivity is important in determining whether there is a feedback in their causality. It reaffirms that these variables have a bidirectional causality, where each of them causes one another. I perform unit root and cointegration tests before regressing the error-correction and Granger bivariate and multivariate causality models. These results provide evidence of a short-run as well as a long-run causality between export and productivity.

Chapter Four contributes by examining whether industry level data support the country level findings. Capital intensity (the ratio of capital stock to employment) and average size (the ratio of real gross output to number of establishments in the industry) variables are included in the model as other possible variables that can influence both or either export or productivity, and directly or indirectly. Besides finding a bidirectional causality between export and productivity, my results show that there is a possibility of an indirect causality between them through size and capital intensity.

5.3 Policy Implications

It is a major concern of policy makers to formulate economic policies that are effective and relevant to the needs of the industries and the economy as a whole. Among alternative options, policy makers can select the appropriate policy based on empirical evidence. In this study, I carry out empirical analyses on a panel of manufacturing industries in Malaysia and the United Kingdom. As my data is country specific, these datasets can be used in policy formulation at the country specific level.

From my findings, it is clear that size, besides other determinants, is an important determinant to labour productivity. The performance of the manufacturing industries in Malaysia is dependent on the average size of the industries. The coefficients of average size in the short run have a major impact on the performance of industries compared to the long run coefficients. This implies that the industries quickly adjust to the long run equilibrium. In reference to the proxies used to measure size, I find that paid-up capital and the number of employees are not effective measures for size as a determinant to labour productivity. Therefore, it is recommended that annual sales turnover is used as a better measure of size. In allocating funds in support of the small and medium industries development, government agencies should use annual sales turnover as a basis to distribute funds because it reflects more of the industry size compared to paid-up capital and number of employees.

My results also indicate that there is an important role played by capital intensity (capital-labour ratio) and intermediate material in determining labour productivity. This requires investment in appropriate technology, and good quality materials to be in place, in order to provide the impetus for sustainable industry performance.

Based on Chapter Three, the following policy implications are identified. The study points to the importance of R&D for economic growth, especially R&D efforts made collectively by the business enterprises and those from foreign sources. It also shows a strong collective effort by all domestic business R&D is important to the total factor productivity of an industry. Business R&D has high spillover effects, making its social return higher than its private return. This phenomenon enhances the ability of the business sector to absorb technology coming from other industries and abroad. This strong spillover effects justify some sort of government support to business R&D being aware that the larger business population would benefit from it. As the effect of foreign R&D on the productivity of UK's manufacturing industries is high and significant, the government should ensure the openness of its country to foreign technology, either through the flows of goods and services, of people or of ideas. The government should also facilitate and encourage the local firms' absorptive capabilities needed for making the best of foreign technology.

From Chapter Four, it is concluded that exports plays an important role in determining productivity and vice versa, in the case of Malaysia. The efforts made by the Malaysian government so far, like market promotion, technical assistance, and training, advisory and consultancy services, are supportive towards this cause. The challenge lies on improving the competitiveness of Malaysia's manufacturing exports in the increasingly globalised market. Conforming to the findings in Chapter Three, the industries should see this challenge as an opportunity and therefore, go through a transition from a product-based economy to a knowledge-based economy, where science, technology and innovation are vital to economic success. The rapid technology advances, changing business models, new routes to market, and competitiveness pressures, lead to a demand for increased productivity. Industries should venture into new markets and/or increase their market share. They should cooperate in R&D to create new products, services and process. Well-developed business networks will become increasingly important mechanisms for driving success.

5.4 Recommendations for Further Studies

This dissertation does not focus on whether Gibrat's Law is supported by the manufacturing industries in Malaysia. According to Gibrat, firm growth rates are proportionate to size. An evaluation into whether the Malaysia case conforms to this Law would add to the literature in this field. Besides that, industry specific studies may be able to shed more lights into what is relevant to such industry. This would assist the government to come up with policies that are relevant to specific industries, rather than a generalisation on all industries in the manufacturing sector or economy. Other related variables may also be tested into similar models, to test the results on productivity. Other than exports, for instance, openness can be used to represent trade activities as a determinant to productivity.

In the perspective of having R&D efforts, it is recommended that interactions of R&D intensity with other domestic R&D and foreign R&D are made to identify whether their R&D intensity improve their absorptive capability to R&D efforts made by other domestic industries and foreign countries. For country level studies, the effects of R&D performed in the public sector, in particular in the institutes of higher learning, can also be analysed if it offers substantial and comparable impact on the industries' TFP. Finally, future research could also focus on whether R&D intensity makes any difference on the impact of public sector R&D. This would shed more light into the networking between the public sector and the business sector on the transfer of technology know-how.

Appendix A

Procedures in Testing for Unit Roots

I perform two panel unit root tests in Chapters 3 and 4. I use 2 tests in each chapter to confirm the results of each of the test and identify the possibility of certain tests to be inconsistent with the other. These tests are grouped based on their assumption on homogeneity or heterogeneity processes. If these tests confirm nonstationarity in the data, the data will have to be transformed into differences to make it a valid regression[1]. If the variables are stationary at first difference, then they are considered as integrated of order 1, I(1). In Chapter Three, I use Levin, Lin and Chu (2002) and Maddala and Wu (1999), and in Chapter Four I use Im, Pesaran and Shin (2003) and Choi (1999). Both Maddala and Wu (1999) and Choi (1999) use Phillip Perron-fisher type tests. To differentiate these two tests, Maddala aand Wu (1999) is abbreviated as PPF, and Choi (1999) as PPC.

Panel unit root tests are similar, but not identical, to unit root tests carried out on a single series. Single series are known to have low power of standard unit root tests, and is considered common practice among applied researchers. However, testing for panel unit roots is recent, see Phillips and Moon (1999), Maddala and Wu (1999), Harris and Tzavalis (1999), Hadri (2000), Choi (2001), Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003). There are earlier contributions like Breitung and Meyer (1994) and Quah (1994), besides a few others[2]. I am classifying my unit root tests on the basis of whether there are restrictions on the autoregressive process across cross-sections or series, i.e. (1) that assumes homogeneous unit root process, and (2) that assumes

[1] By taking differences, the information contained in the regression will not be the same as when it is in levels.
[2] Boumahdi and Thomas (1991) and Bhargava et al (1982).

heterogeneous unit root process Consider the following basic autoregressive process, AR(1), in panel data for illustration.

$$y_{it} = \rho_i y_{it-1} + X_{it}\delta_i + \varepsilon_{it} \qquad \text{(A.1)}$$

where $i = 1, 2, 3, \ldots\ldots, N$

$t = 1, 2, 3, \ldots\ldots, T$

The ρ_i are the autoregressive coefficients, X_{it} are the exogenous variables in the equation, which may include either fixed effects or individual trends or both, and ε_{it} are the errors, which are assumed to be mutually independent idiosyncratic disturbance. If $|\rho_i| = 1$, then y_{it} is said to be nonstationary or contains a unit root. On the other hand, if $|\rho_i| < 1$, then y_{it} is said to be stationary or weakly stationary. When we assume homogeneous unit root process, we are assuming that the persistence parameters are common across industries so that $\rho_i = \rho$ for all i. The tests that employ these assumptions are LLC, Breitung and Hadri. Alternatively, when we assume heterogeneous unit root process, we are allowing the ρ_i to vary freely across industries. The tests that employ this assumption are Im, Pesaran and Shin (IPS), Maddala and Wu (MW) and Choi tests. See detail discussion on each test below.

A1.0 Levin, Lin and Chu Test

According to LLC, single series unit root test procedures are known to have limited power against alternative hypothesis with high persistent deviations from equilibrium. Campbell and Perron (1991) simulation prove that this problem is particularly severe for small samples. LLC consider pooling cross-section time series data as a means of generating more powerful unit root tests than performing a separate unit root test for each individual. They design test procedures to evaluate the null hypothesis that each individual in the panel has integrated time series versus the alternative hypothesis that all individuals time series are stationary. LLC maintain hypothesis is

$$\Delta y_{it} = \delta y_{it-1} + \sum_{L=1}^{P_i} \theta_{iL} \Delta y_{it-L} + \alpha_{mi} d_{mt} + \varepsilon_{it} \ , \qquad m = 1, 2, 3. \qquad \text{(A.2)}$$

m represents the three data generating processes models, i.e.:

Model 1 : $\Delta y_{it} = \delta y_{it-1} + \zeta_{it}$

Model 2 : $\Delta y_{it} = \alpha_{0i} + \delta y_{it-1} + \zeta_{it}$

Model 3 : $\Delta y_{it} = \alpha_{0i} + \alpha_{1i} t + \delta y_{it-1} + \zeta_{it}$

where $-2 < \delta \leq 0$ for i = 1, …., N. Model 1 excludes both the constant and time trend. Model 2 include the constant (individual-specific mean) only, whereas Model 3 includes both the constant and time trend. α_m is used to indicate the corresponding vector of coefficients for a particular model, m = 1, 2, 3 and d_{mt} is used to indicate the vector of deterministic variables.

Since p_i is unknown, they suggest a three-step procedure to implement their test. In Step 1, they perform separate ADF regressions for each individual in the panel, determine the autoregression order, p, and run two auxiliary regressions to generate orthogonalised residuals by running Δy_{it} and y_{it-1} against $\Delta y_{it-L} (L = 1,...., p_i)$ and the appropriate deterministic variables, d_{mt}, as shown below:

$$\Delta y_{it} = \sum_{L-1}^{p} \pi_{iL} \Delta y_{it-L} + \hat{\alpha}_{mi} d_{mt} + \hat{e}_{it} \qquad \text{(A.3)}$$

therefore $$\hat{e}_{it} = \Delta y_{it} - \sum_{L-1}^{p} \pi_{iL} \Delta y_{it-L} - \hat{\alpha}_{mi} d_{mt} \quad \text{(A.4)}$$

and

$$y_{it-L} = \sum_{L-1}^{p} \pi_{iL} \Delta y_{it-L} + \hat{\alpha}_{mi} d_{mt} + \hat{v}_{it} \quad \text{(A.5)}$$

therefore $$\hat{v}_{it} = y_{it-L} - \sum_{L-1}^{p} \pi_{iL} \Delta y_{it-L} - \hat{\alpha}_{mi} d_{mt} \quad \text{(A.6)}$$

To control for heterogeneity across individuals, these residuals are normalised by the regression standard error in the following equations.

$$\tilde{e}_{it} = \frac{\hat{e}_{it}}{\hat{\sigma}_{\varepsilon i}}, \qquad \tilde{v}_{it-1} = \frac{\hat{v}_{it-1}}{\hat{\sigma}_{\varepsilon i}}$$

In Step 2, they estimate the ratio of long run to short run standard deviations. The long-run variance for Model 1 under the null hypothesis of a unit root can be estimated as follows:

$$\hat{\sigma}_{yi} = \frac{1}{T-1} \sum_{t=2}^{T} \Delta y_{it}^2 + 2 \sum_{L=1}^{\bar{K}} w_{\bar{K}L} \left[\frac{1}{T-1} \sum_{t=2+L}^{T} \Delta y_{it} \Delta y_{it-L} \right] \quad \text{(A.7)}$$

where parameter $\bar{K}$ is a truncation lag that can be data-dependent. $\bar{K}$ must be obtained in a manner[3] that ensures the consistency of $\hat{\sigma}_{yi}^2$. The covariance weights $w_{\bar{K}L}$ depend on the choice of kernel. If a Bartlett kernel is used, for instance, $w_{\bar{K}L} = 1 - \frac{L}{\bar{K}+1}$. For each cross-section *i*, LLC define the ratio of the long-run standard deviation to the innovation standard deviation as:

[3] As suggested by Andrew (1991).

$$\hat{s}_i = \frac{\hat{\sigma}_{yi}}{\hat{\sigma}_{\varepsilon i}} \tag{A.8}$$

The standard deviation ratio is estimated by $\hat{S}_N = \frac{1}{N}\sum_{i=1}^{N}\hat{s}_i$. This statistic will be used to adjust the mean of the t-statistic in Step 3.

In Step 3, they compute the panel (pooled) test statistics to estimate

$$\tilde{e}_{it} = \delta\tilde{\upsilon}_{it-1} + \tilde{\varepsilon}_{it} \tag{A.9}$$

A2.0 Phillip-Perron-Fisher

As an alternative approach to Levin, Lin and Chu tests, Maddala and Wu (1999) and Choi (2001) propose to use augmented Dickey Fuller-Fisher (ADF-Fisher) and Phillips Perron-Fisher (PP-Fisher) to derive tests that combine the p-values from individual unit root tests. Similar to IPS, ADF-Fisher and PP-Fisher have the null hypothesis of unit root and alternative hypotheses of some cross-sections without unit root. Maddala and Wu (1999) and Choi (2001) propose the following Fisher-type test which combines the p-values from unit root test from each cross-section i to test for unit root in panel data.

$$\lambda = -2\sum_{i=1}^{N}\log_e \pi_i \tag{A.10}$$

Note that the equation has a χ^2 distribution with $2N$ degrees of freedom. This test is performed by Fisher and is called the inverse chi-square test and most widely used in meta-analysis. In addition, Choi further define the Z test statistics, as proposed by Stouffer et al (1949), as follows:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1} \pi_i \qquad \text{(A.11)}$$

where $\Phi(\bullet)$ is the standard normal cumulative distribution function. It is called the inverse normal test because $0 \leq \pi_i \leq 1$ and $\Phi^{-1}(\pi_i)$ is the normal random variable.

A3.0 Im, Pesaran and Shin

According to IPS (2003), LLC test is restrictive in the sense that it requires ρ to be homogenous across i. They propose an alternative unit root tests for dynamic heterogenous panels based on the mean of individual unit root statistics. A standardised t-bar test statistic based on the Augmented Dickey-Fuller statistics is averaged across the groups. The basic framework is given by the stochastic process, y_{it}, which is generated by the first order autoregressive process:

$$y_{it} = (1 - \phi_i)\mu_i + \phi_i y_{it-1} + \varepsilon_{it}, \quad i = 1, \ldots\ldots, N \quad t = 1, \ldots\ldots, T, \qquad \text{(A.12)}$$

where the initial values, y_{i0}, are given. IPS is testing the null hypothesis of each series in the panel contains a unit root, and the alternative hypothesis allows for some of the individual series (but not all) to have unit roots. Equation (14) can be expressed as

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \varepsilon_{it} \qquad \text{(A.13)}$$

where $\alpha_i = (1-\phi_i)\mu_i$, $\beta_i = -(1-\phi_i)$ and $\Delta y_{it} = y_{it} - y_{it-1}$. The null hypothesis of unit roots is then expressed as:

$$H_0 : \phi_i = 0 \text{ for all } i$$

while the alternative hypothesis is given by:

$$H_1 : \begin{cases} \beta_i < 0, & i = 1, 2, \ldots., N_1 \\ \beta_i = 0, & i = N_1+1, N_1+2, \ldots\ldots., N. \end{cases}$$

This requires a non-zero fraction of the individual processes to be stationary.

Appendix B

Procedures in Testing for Cointegration

In performing cointegration tests, I use Kao's (1999) Dickey-Fuller and augmented Dickey-Fuller types tests, and Pedroni (1999) tests. They provide us with the opportunity to compare the results from two different tests that assume homogenous and heterogenous panels. Both tests have a null hypothesis of no cointegration. In Chapter Three, I apply bias-corrected OLS and fully modified OLS estimators to all these tests and analyse how these estimators may provide different results to the same dataset. In Chapter Four, I apply bias-corrected OLS and dynamic OLS estimators. The purpose of testing for cointegration is to determine whether a group of non-stationary series are cointegrated or not. Non-stationarity time series are said to be cointegrated if there is a stationary linear combination of two or more of them (Engle and Granger, 1987). It may be interpreted as long run equilibrium relationship among variables. Cointegration test is performed to determine whether TFP and R&D have a long run relationship.

If the y_{it} and x_{it} are both I(1) and there exists a β such that $\varepsilon_{it} = y_{it} - \beta x_{it}$ is I(0), y_{it} and x_{it} are cointegrated, with β being called the cointegrating parameter, or more generally, $(1, -\beta)'$ being the cointegrating vector. When this occurs, a special constraint operates on the long-run components of y_{it} and x_{it}. Since both y_{it} and x_{it} are I(1), they will be dominated by 'long wave' components (Verbeek, 2000), but ε_{it}, being I(0), will not be. This is related to the concept of a long run equilibrium, of which equilibrium is defined by

$$y_{it} = \alpha_i - \beta x_{it} \qquad \text{(B.1)}$$

Then $e_{it} = \varepsilon_{it} - \alpha_i$ is the equilibrium error, which measures the extent to which the value of y_{it} deviates from its equilibrium value $\alpha_i - \beta x_{it}$. If e_{it} is I(0), the equilibrium error is stationary and therefore, fluctuating around zero. The system will, on average, be in equilibrium. However, if e_{it} is I(1), y_{it} and x_{it} are not cointegrated. Consequently, the equilibrium error can wander widely and zero crossings would be very rare. Under such circumstance, y_{it} and x_{it} do not have a long run relationship. The presence of a cointegrating vector can, therefore, be interpreted as the presence of a long run equilibrium relationship.

Details of Kao (1999) and Pedroni(1999) tests are given below.

B1.0 KAO TESTS

A panel regression model is considered as follows,

$$y_{it} = x_{it}'\beta + z_{it}'\gamma + e_{it} \qquad \text{(B.2)}$$

Where y_{it} and x_{it} are I(1) and noncointegrated. Kao (1999) proposed Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) types unit root tests for e_{it} to test for the null of no cointegration. Both of these types of tests are carried out on residuals obtained from OLS and either fully modified OLS and dynamic OLS estimators in Chapters 3 and 4. The DF type tests can be calculated from the following fixed effect residuals,

$$\hat{e}_{it} = \rho\hat{e}_{it-1} + v_{it} \qquad \text{(B.3)}$$

Where $\hat{e}_{it} = \tilde{y}_{it} - \tilde{x}_{it}'\hat{\beta}$ and $\tilde{y}_{it} = y_{it} - \bar{y}_{i.}$. The null hypothesis of no cointegration can be written as $H_0 : \rho = 1$. Kao proposed four types of tests under the DF type.

$$DF_{\rho} = \frac{\sqrt{N}T(\hat{\rho}-1)+3\sqrt{N}}{\sqrt{10.2}} \tag{B.4}$$

$$DF_{t} = \sqrt{1.25}t_{\rho} + \sqrt{1.875N} \tag{B.5}$$

$$DF_{\rho} = \frac{\sqrt{N}T(\hat{\rho}-1)+\dfrac{3\sqrt{N}\hat{\sigma}_{\upsilon}^{2}}{\hat{\sigma}_{0\upsilon}^{2}}}{\sqrt{3+\dfrac{36\hat{\sigma}_{\upsilon}^{4}}{5\hat{\sigma}_{0\upsilon}^{4}}}} \tag{B.6}$$

$$DF_{t}^{*} = \frac{t_{\rho}+\dfrac{\sqrt{6N\hat{\sigma}_{\upsilon}}}{2\hat{\sigma}_{0\upsilon}}}{\sqrt{\dfrac{\hat{\sigma}_{0\upsilon}^{2}}{2\hat{\sigma}_{\upsilon}^{2}}+\dfrac{3\hat{\sigma}_{\upsilon}^{2}}{10\hat{\sigma}_{0\upsilon}^{2}}}} \tag{B.7}$$

Where $\hat{\sigma}_{\upsilon}^{2} = \hat{\sum}_{yy} - \hat{\sum}_{yx}\hat{\sum}_{xx}^{-1}$ and $\hat{\sigma}_{0\upsilon}^{2} = \hat{\Omega}_{yy} - \hat{\Omega}_{yx}\hat{\Omega}_{xx}^{-1}$.

The OLS estimate of ρ and *t*-statistic are given as,

$$\hat{\rho} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{e}_{it}\hat{e}_{it-1}}{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{e}_{it}^{2}} \tag{B.8}$$

And

$$t_{\rho} = \frac{(\hat{\rho}-1)\sqrt{\sum_{i=1}^{N}\sum_{t=2}^{T}\hat{e}_{it-1}^{2}}}{s_{e}} \tag{B.9}$$

Under the ADF type, one test is performed based on the following regression,

$$\hat{e}_{it} = \rho\hat{e}_{it-1} + \sum_{j=1}^{p} \vartheta_j \Delta\hat{e}_{it-j} + \upsilon_{itp} \tag{B.10}$$

Similar to the DF type test, the ADF test has a null hypothesis of no cointegration. The ADF test statistic can be constructed as,

$$ADF = \frac{t_{ADF} + \dfrac{\sqrt{6N}\hat{\sigma}_{\upsilon}}{2\hat{\sigma}_{0\upsilon}}}{\sqrt{\dfrac{\hat{\sigma}_{0\upsilon}^2}{2\hat{\sigma}_{\upsilon}^2} + \dfrac{3\hat{\sigma}_{\upsilon}^2}{10\hat{\sigma}_{0\upsilon}^2}}} \tag{B.11}$$

Where t_{ADF} is the t-statistic of ρ in equation B.3. The asymptotic distributions of these entire tests converge to a standard normal distribution $N(0,1)$ by sequential limit theory.

B2.0 Pedroni (1997, 1999) Tests

Pedroni (1999) studied properties for the case of homogenous and heterogenous cointegrating factors. He showed that in panels, the residual-based tests for the null of no cointegration have distributions that are asymptotically equivalent to 'raw' panel unit root tests iff the regressors are exogenous. Building up on the assumption that the regressors are strictly exogenous, he provides a pooled Phillips and Perron-type test (Kao et al, 1999). The autoregressive coefficients are pooled across different members of the panel for the unit root tests on the estimated residuals.

There are a few important features of Pedroni tests. They allow for the fixed effects to differ across members of the panel and the cointegrating vector to differ across members of the panel (under H_1). Besides allowing for multiple regressors, they also address the heterogeneity in the errors across cross-section units.

Pedroni (1997) formulated seven statistics as follows:

1. Panel v-Statistic: $$T^2 N^{3/2} Z_{\hat{v}N,T} \equiv T^2 N^{3/2} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1}$$

2. Panel ρ-Statistic: $$T\sqrt{N} Z_{\hat{\rho}N,T} \equiv T\sqrt{N} \left(\sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i)$$

3. Panel t-Statistic: $$Z_{tN,T} \equiv \left(\tilde{\sigma}_{N,T}^2 \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^2 \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i)$$
   (non-parametric)

4. Panel t-Statistic: $$Z_{tN,T}^{*} \equiv \left(\tilde{s}_{N,T}^{*2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} \hat{e}_{i,t-1}^{*2} \right)^{-1/2} \sum_{i=1}^{N} \sum_{t=1}^{T} \hat{L}_{11i}^{-2} (\hat{e}_{i,t-1}^{*} \Delta \hat{e}_{i,t}^{*})$$
   (parametric)

5. Group ρ-statistic: $$TN^{-1/2} \tilde{Z}_{\hat{\rho}_{N,T-1}} \equiv TN^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{e}_{i,t-1}^2 \right)^{-1} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$$

6. Group t-statistic: $$N^{-1/2} \tilde{Z}_{t_{N,T}} \equiv N^{-1/2} \sum_{i=1}^{N} \left(\hat{\sigma}_i^2 \sum_{t=1}^{T} \hat{e}_{i,t-1}^2 \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} - \hat{\lambda}_i \right)$$
   (non-parametric)

7. Group t-statistic: $$N^{-1/2} \tilde{Z}_{t_{N,T}}^{*} \equiv N^{-1/2} \sum_{i=1}^{N} \left(\sum_{t=1}^{T} \hat{s}_i^{*2} \hat{e}_{i,t-1}^{2} \right)^{-1/2} \sum_{t=1}^{T} \left(\hat{e}_{i,t-1} \Delta \hat{e}_{i,t} \right)$$
   (parametric)

where

$$\hat{\lambda}_i = \frac{1}{T}\sum_{s=1}^{k_i}\left(1-\frac{s}{k_i+1}\right)\sum_{t=s+1}^{T}\hat{\mu}_i,\hat{\mu}_{i,t-s}, \quad \hat{s}_i^2 \equiv \frac{1}{T}\sum_{t=1}^{T}\hat{\mu}_{i,t}^2, \quad \hat{\sigma}_i^2 = \hat{s}_i^2 + 2\hat{\lambda}_i,$$

$$\tilde{\sigma}_{N,T}^2 \equiv \frac{1}{N}\sum_{i=1}^{N}\hat{L}_{11i}^{-2}\hat{\sigma}_i^2, \quad \hat{s}_i^{*2} \equiv \frac{1}{t}\sum_{t=1}^{T}\hat{\mu}_{i,t}^{*2}, \quad \tilde{s}_{N,T}^{*2} \equiv \frac{1}{N}\sum_{i=1}^{N}\hat{s}_i^{*2},$$

$$\hat{L}_{11i}^2 = \frac{1}{T}\sum_{t=1}^{T}\hat{\eta}_{i,t}^2 + \frac{2}{T}\sum_{s=1}^{k_i}\left(1-\frac{s}{k_i+1}\right)\sum_{t=s+1}^{T}\hat{\eta}_{i,t}\hat{\eta}_{i,t-s}$$

and where the residuals $\hat{\mu}_{i,t}, \hat{\mu}_{i,t}^{*}$, and $\hat{\eta}_{i,t}$ are obtained from the following regressions:

$$\hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \hat{\mu}_{i,t}, \quad \hat{e}_{i,t} = \hat{\gamma}_i\hat{e}_{i,t-1} + \sum_{k=1}^{K_i}\hat{\gamma}_{i,k}\Delta\hat{e}_{i,t-k} + \hat{\mu}_{i,t}^{*},$$

$$\Delta y_{i,t} = \sum_{m=1}^{M}\hat{b}_{mi}\Delta x_{mi,t} + \hat{\eta}_{i,t}$$

The null hypothesis of Pedroni's tests is no cointegration.

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