A Comparison of Northern Ireland's Productivity and Efficiency across Services and Manufacturing

Technical Report 1

Study on Productivity, Innovation and Competitiveness in Small Open Economies

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Bradford University School of Management

Manchester Institute of Innovation Research, Manchester Business School

University College Cork, Department of Economics,

Preface

A Comparison of Northern Ireland's Productivity and Efficiency across Services and Manufacturing is the first of four reports produced by the study on *Productivity, Innovation and Competitiveness in Small Open Economies (PIC SOE).* The PIC SOE project is a research study commissioned by the Department of Enterprise, Trade and Investment (DETI) in 2009 to investigate approaches and strategies for advancing productivity, innovation and competitiveness in the three leading small open economies of Singapore, New Zealand, and the Republic of Ireland so as to draw insights for Northern Ireland.

The PIC SOE project is undertaking economic performance, industry, and policy analyses of these small open economies and of key sectors within them, including emerging technology industries, chemicals, processed food, and advanced services. Three technical reports are being delivered: 1. *A Comparison of Northern Ireland's Productivity and Efficiency across Services and Manufacturing* (this report); 2. *Mapping Organizational Capabilities for Innovation and Competitiveness: Research Performance and Patenting in Small Open Economies*; and 3. *Competitiveness and Innovation Profiles of Three Small Open Economies: New Zealand, Singapore, and Republic of Ireland.* A final report, *Productivity, Innovation and Competitiveness in Small Open Economies*, will provide an overview of the findings of these earlier reports and assesses the applicability, comparability, and significance of the findings for policy development in Northern Ireland to support the region's prosperity, innovativeness, and industrial productivity.

The PIC SOE study team comprises: Dr. Adrian T.H. Kuah (University of Bradford, UK); Prof. Philip Shapira (Manchester Institute of Innovation Research, Manchester Business School, University of Manchester, UK); Dr. Eleanor Doyle (Institute for Business Development and Competitiveness, Department of Economics, University College Cork, Republic of Ireland); and Dr. Damian R. Ward (University of Bradford, UK). Additional research assistance is provided by Lasandahasi Ranmuthumalie de Silva, Fergal O'Connor, Gary Marsh and Luciano Kay.

This report examines the productivity and efficiency of leading firms in selected sectors relative to other firms and against international benchmarks. The report was written Damian Ward, Eleanor Doyle, Philip Shapira, and Adrian Kuah. Any opinions, findings, and recommendations expressed in this report are those of the authors and do not necessarily reflect the views of DETI. Some information and analyses included in this report have been updated prior to use in the PIC SOE final study report.

Contents

Executive Summary

Internationally traded sectors are capable of transferring wealth into a region and are, therefore, central to the development of economic prosperity. This report examines the productive efficiency of important internationally traded sectors across manufacturing and advanced services. The Small Open Economies (SOEs) of Republic of Ireland, Singapore and New Zealand are selected as comparator economies for Northern Ireland. These are developed economies for which the sectors of Banking, Chemical and Food serve as internationally traded sectors of reference. The report estimates efficiency over the period of the mid 2000's within each location and also across the locations, enabling a comparison of Northern Ireland's efficiency against the other SOEs.

Data Envelopment Analysis (DEA) is used to measure technical efficiency, scale efficiency, and the development of efficiency over time for each sector and location. This permits analyses, within and across our selected SOEs, of the extent to which (a) leading firms maximise their output given their inputs - technical efficiency; (b) leading firms operate at a scale of production appropriate to producing output at relatively low cost - scale efficiency; and (c) how the productivity performance across such firms has changed over time.

The findings provide many grounds for optimism from the perspective of Northern Ireland. However, some efficiency issues are identified within Northern Ireland's banking, chemicals, and food sectors as follows:

In **banking**, Northern Ireland is ranked lowest in technical efficiency when compared across our comparator economies (pooled analysis). Whether this reflects true underlying technical efficiency inferiority or is attributable to differences in the *nature* of value-added services provided and performed in each economy's Banking sector deserves further analysis. Notwithstanding this finding, best practice within the sector is strong and Total Factor Productivity has grown at over 4% per annum, the highest across our sample of countries.

In **chemicals**, Northern Ireland displays sound performance in technical and scale efficiency, as Singapore and New Zealand are surprisingly poorer performers. As with the Banking sector, the scale efficiency of firms in Northern Ireland, relative to the comparator economies, indicates they are operating at a relatively more efficient scale – neither too big nor too small. Growth in Total Factor Productivity has improved most in the sector for Northern Ireland compared to Singapore and New Zealand. (The Republic of Ireland was excluded from analysis in this sector due to data limitations.)

In **processed food**, weaker technical and scale efficiency is evident for Northern Ireland relative to the same sectors in the Republic of Ireland, Singapore and New Zealand. Again it is important when interpreting these results to bear in mind that the competitive features of the sectors are very different across the economies and the relatively strong performance of companies in Northern Ireland for scale efficiency (pooled results) points to this. Best practice within the sector is strong and Total Factor Productivity has grown at 4.4% per annum.

Taken together, the report suggests that while productive efficiency is strong in Northern Ireland, there may be opportunities for improvement in banking and processed foods. This finding may help to guide additional efforts to generate increased economic prosperity from trading in the global economy. Firms in Northern Ireland display a trend of improving productivity and in improving best practice year on year indicating a learning capability across firms in the sectors considered. Subsequent analyses (in following parts of the PIC SOE study) will turn to a closer examination of how this is achieved and how the rate of growth can be supported.

1. Introduction

This report examines the productive efficiency of the banking, chemicals and food sectors in Northern Ireland and also compares their efficiency against the same sectors in New Zealand, Singapore and the Republic of Ireland. Being small, developed and reasonably fast growing economies, New Zealand, Singapore and the Republic of Ireland are seen as relevant benchmarks for the Northern Ireland economy. The chosen sectors represent advanced services and manufacturing bases of each economy. In addition, banking, chemicals, and food are leading export sectors within the comparator group of economies. Export oriented or export intensive sectors often indicate an international competitive advantage (see Porter 1990). As such, internationally strong export oriented sectors have the potential to generate high value-added employment for the economy, high incomes for employees, and contribute to prosperity within a region. Therefore, understanding the level and growth of productive efficiency within a selective range of sectors in Northern Ireland; as well as in comparison with other economies, is valuable to policymakers interested in promoting economic growth and prosperity across Northern Ireland.

This investigation uses Data Envelopment Analysis, DEA, to examine the efficiency of firms. DEA was developed by Charnes, Cooper and Rhodes (1978) and involves the estimation of a 'best practice' frontier against which all firms are then measured. DEA is non-parametric in nature - offering flexibility as a method appropriate to this investigation - is a variant of linear programming and is supported in a number of analytical software packages. In particular, sectors investigated previously included banking, see Santiago, Humphrey and López del Paso *(*2007); chemicals, see Viverita and Ariff (2008); and food, see Kumar and Basu (2008).

The analytical approach has a number of strands. First, the efficiency of each sector within each economy is examined. This provides a comparison of efficiency initially amongst domestic firms. This involves the estimation of a single frontier of best practice. Next, the efficiency within each sector *across* economies is compared. This approach involves the estimation of a pooled frontier of best practice where the relevant dataset under analysis is a pool of observations in all economies. This analysis enables a comparison of firms in Northern Ireland against best practice in the other economies. Finally, the analysis examines the development of productivity over time addressing the speed at which productivity in Northern Ireland changes year on year and focusing on issues such as the sources of productivity growth and a comparison of how productivity growth in Northern Ireland compares with growth in the other economies under investigation.

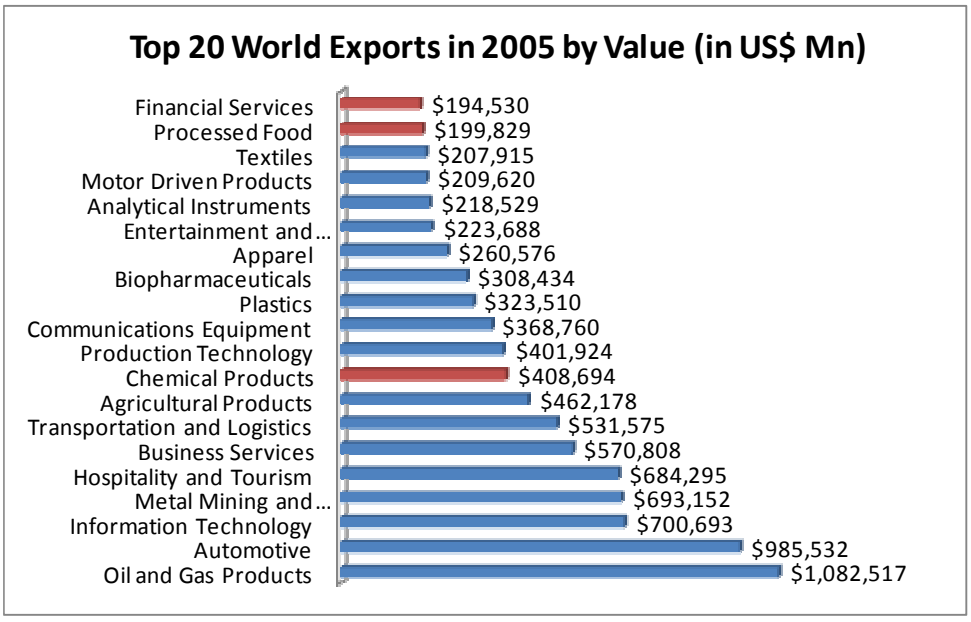
In Section Two, the selection of the three sectors is outlined with a background commentary on the size, strength and nature of the banking, chemicals, and food sectors in each economy. Section Three provides the technical framework for understanding efficiency as well as an explanation of how Data Envelopment Analysis is undertaken. Section Four discusses the selection of variables and the data collection process. Section Five presents results and offers a summary. Section Six presents our conclusions.

2. Sector Selection

Economic activities that produce goods and services domestically, and trade domestically, have economic value of creating jobs and producing domestic goods and services. But they generally transfer wealth amongst the various stakeholders within the economy. Such sectors are arguably not best placed to generate increased wealth for an economy.

On the other hand, leading export-intensive sectors have to be more competitive in order to produce goods and services that are able to trade internationally (as well as locally). As these sectors sell to overseas customers, then through revenue receipts, wealth may be transferred into the economy. Economies benefitting from export-led growth experience wealth generation and economic prosperity. Competitiveness on a global scale is seen by Porter (1990) to stem from value-added features of a product or service. Being competitive on cost and price is easily mimicked by other low-wage economies. Being competitive on process, design, manufacture, technology and delivery, require higher order skills which ultimately lead to goods or services with a higher value-added. With customers being willing to pay more for higher valued goods and services, then for Porter (1990), successful exports are a sure sign of high value-added; and high value-added means higher prices, higher wages and improved economic prosperity.

Figure 1



Source: Data taken from the Institute for Strategy and Competitiveness, Harvard Business School.

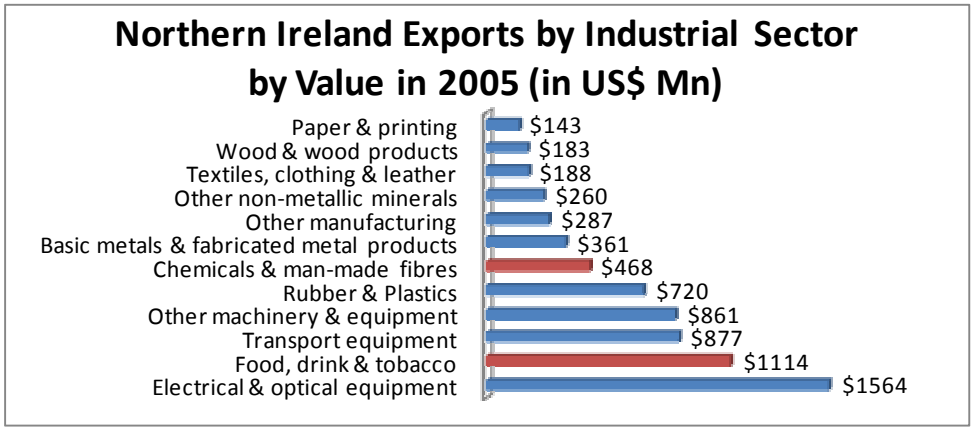
Sector and Industry Shares – Output and Exports

In this context, this report seeks to examine the productivity of Northern Ireland's leading export sectors against similar sectors in the benchmark economies of Singapore, the Republic of

Ireland and New Zealand. To identify leading export sectors worthy of further analysis given the brief of this research project, data from the Institute for Strategy and Competitiveness, Harvard Business School (latest data refer to 2005) was examined for the countries in our study while data for Northern Ireland was taken from statistical releases produced by DETI, Northern Ireland. A substantial advantage of the data from the ISC, HBS, is that both Manufacturing and Services data are amalgamated to allow for a comprehensive analysis and international comparison of economic activities. To provide some context for our study, the global export perspective is offered first in Figure 1.

In terms of the global economy, the most exported good or service in 2005 was Oil and Gas. Chemical Products ranked ninth, Processed Food was nineteenth and Financial Services was twentieth. For Northern Ireland, Figure 2 indicates the most significant manufacturing export sectors in 2005. In export terms, the main sector is Electrical and Optical Equipment (24%), followed by Food (14%), closely followed by Transport Equipment (13%) and Other Machinery and Equipment. Chemicals is ranked 6th in terms of value of exports.

Figure 2



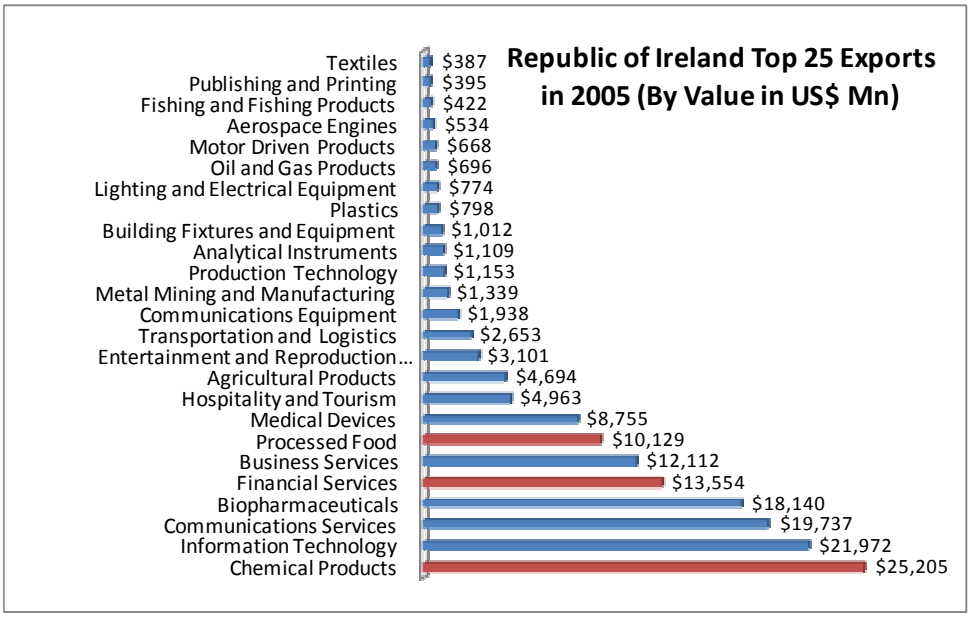
Source: Northern Ireland Manufacturing Sales & Exports Survey 2005/06 (DETI, Northern Ireland);

Such sales and export activities are important for the economy, yet over 80% of employment is engaged in Services activities, hence it is vital to consider such economic activities.[1] Given their contribution to the Gross Value Added (GVA) in Northern Ireland, the most important Services activities are Distribution (Wholesale & Retail) contributing 40% to total Services GVA, Business Services & Finance reflects the activity of all financial institutions and also Real Estate, Renting and other business activities, contributing 31% of NI's GVA.[2]

Figure 3 illustrates the leading export sectors for the Republic of Ireland. Chemical Products appear first, Financial Services, fifth and Processed Food is seventh in the economy. In terms of their global export value, the Republic of Ireland is the fourth largest global exporter of Chemical Products, fifth in Financial Services and seventh in Processed Food.

[1] Figures based on *Monthly Labour Market Report*, July 2009 published by DETI
[2] Figures based on Northern Ireland Index of Services (Experimental) Quarter 1 2009, published by DETI.

Figure 3



Source: Data taken from the Institute for Strategy and Competitiveness, Harvard Business School.

In Singapore, as Figure 4 reveals, exporting activity is more specialised with IT services by far the largest export sector. This is followed by a number of smaller sectors, including Chemical Products, (sixth), Financial Services, (fifteenth); and Processed Food (twenty second) in the Singapore's economy. In terms of their global export value, Singapore is the 11th largest exporter of Chemical Products, 11th in Financial Services and 23rd in Processed Food.

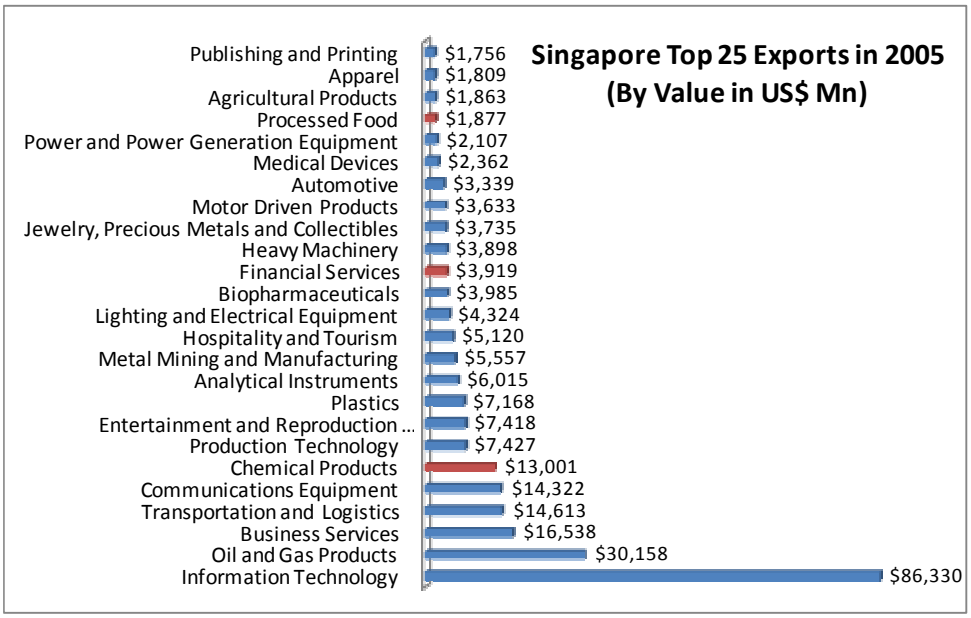
Coupled with Tourism, Agricultural Products and Processed Food are key export sectors in New Zealand, as shown in Figure 5. Chemical products is the eighth largest export sector in New Zealand's economy, while Financial Services is relatively smaller and ranks thirty second. In terms of their global export value, New Zealand ranks the 13th largest exporter of Processed Food, 42nd in Chemical products and 61st in Financial Services.

Not to be unexpected, the size and performance of various sectors both within the world economy, as well as those of Northern Ireland, Republic of Ireland, Singapore and New Zealand varies. However, using data from the Institute for Strategy and Competitiveness, led by Michael Porter,[3] it is clear that our chosen sectors of Banking, Chemicals and Food Processing are generally important across all of our sample economies and region.

The next section offers an outline on the main characteristics of each of these selected sectors within each economy.

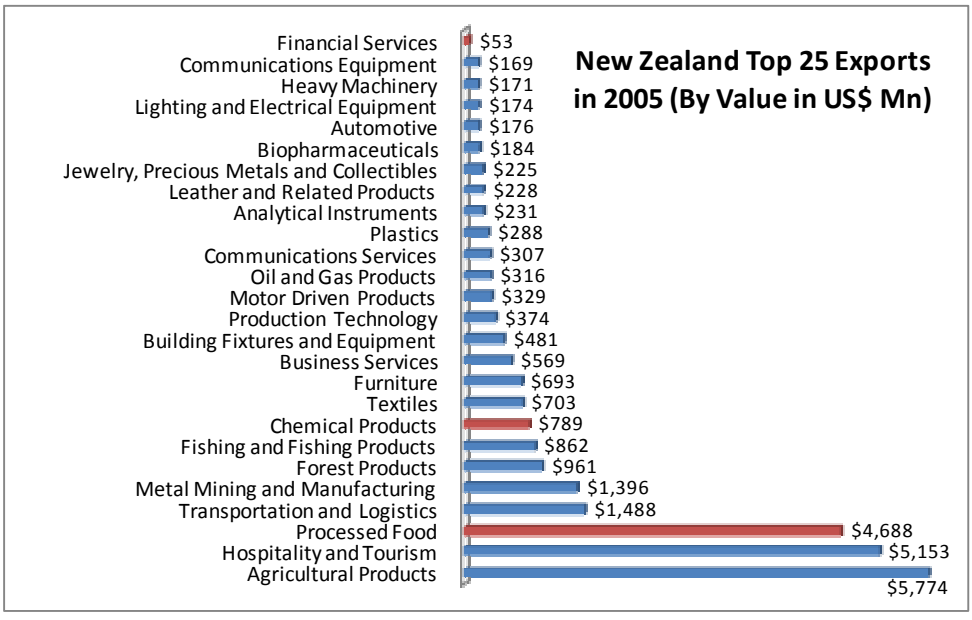
[3] Prof. Porter is recognised as an international authority on International Competitiveness and Productivity, as well as Strategy.

Figure 4



Source: Data taken from the Institute for Strategy and Competitiveness, Harvard Business School.

Figure 5



Source: Data taken from the Institute for Strategy and Competitiveness, Harvard Business School.

Sector Characteristics

Northern Ireland (NI)

Many banks in Northern Ireland are subsidiaries of banks in the UK, Republic of Ireland or elsewhere in the EU. The "Big 4" are: Bank of Ireland; Ulster Bank (subsidiary of Royal Bank of Scotland); Northern Bank (subsidiary of Danske Bank); and First Trust (subsidiary of Allied Irish Bank). These continue to dominate the market to the extent that competition authorities have investigated and found a number of areas where competition could be improved.[4] The "Big 4" hold over 50% of the market (well over 60% for current accounts) –credit cards, personal loans etc – with the remainder shared fairly evenly over a range of institutions. In mortgages and savings, building societies and former building societies (Halifax, Abbey, Nationwide, Woolwich) have comparable market shares to the Big 4. This report will provide an analysis based on Allied Irish Bank, Northern Bank and Ulster Bank.

The Chemical sector (SIC 24) had a total gross turnover of £410 and £460mn in 2005 and 2006 respectively. The chemical sector employed about 3,350 workers in 2006 compared with 7600 in the plastics and rubber sector. This meant that GVA per capita for chemical was one of the highest in manufacturing at £70,293 compared with £38,954 for manufacturers of plastic and rubber products. Chemical represents about 3% of total manufacturing sales, but about 6% of manufacturing value added. A further 7% of manufacturing value added is accounted for by production of plastics and rubber (SIC 25) implying that the wider definition of Chemicals accounts for approximately 13% of manufacturing value added. Sales of plastic and rubber also were approximately double that of Chemicals at £900mn.[5] Data on seventeen firms from the Chemical sector are analysed in this report.

The Food and drink sector had a total gross turnover of £6.3bn in 2006, employing about 18,700 people. The total GVA amounted to almost £1.1bn in 2006 resulting in GVA per capita of £56,359.[6] Exports of processed food outside Northern Ireland represented 65% of total sales in 2006 with Great Britain accounting for 41% of sales in 2006. This sector's sales into export markets represented 13.7% of Northern Ireland's total manufacturing export sales in 2006.[7] The Food and drinks processing sector accounted for 43.5% of total manufacturing sales; 21% of manufacturing employment; and 26.3% of manufacturing value added in 2006. The DETI has provided data for more than 100 firms in the Food Processing sector, and these are analysed for their productive efficiency.

New Zealand (NZ)

The Banking sector in New Zealand is also dominated by subsidiaries of overseas banks, largely from Australia. A recent analysis by its central bank in 2007 indicated NZ banks were

[4] See the Report of the Competition Commission, *Personal Current Account Banking Services In Northern Ireland - Market Investigation*, 2007.
[5] See the Northern Ireland Annual Business Inquiry, 2006,
[6] These data are reported in the Northern Ireland Annual Business Inquiry, 2006, DETI.
[7] As reported by the association Northern Ireland Food and Drink in its *Facts and Figures*.

providing retail banking service to domestic and corporate customers at comparable levels of efficiency to banks in a wide range of developed countries. As of May 2009 there were 18 banks registered in New Zealand with assets approximately NZ$ 400bn (approx US$ 220bn). Retail Banking is dominated by the "Big 4" Australian banks – West Pac, NAB, ANZ and Commonwealth Bank of Australia. Other international banks are present (HSBC, Deutsche Bank, etc), operating largely in corporate/wholesale markets, although some do have a retail presence (e.g. HSBC)[8]. Wholesale, capital and equity markets are very small and relatively underdeveloped. In terms of financial services exports, New Zealand is not prominent. Data from six banks based in New Zealand are examined in our efficiency analysis, namely, ABS, ANZ, BoNZ, Deutsche Bank, HSBC and Westpac.

The Food and drink sector contributes about 10% of New Zealand's GDP, as it benefits from the primary sector of the economy in fishing and agriculture (like the dairy and kiwifruit sectors). Food and beverages production accounts for almost half of the economy's manufacturing activities and employs approximately 20% of the workforce.[9] The composition of the sector is diverse, ranging from large primary food-producing firms, to an emerging cohort of medium-sized firms exporting to niche global markets, and a long tail of small firms servicing the domestic market. The *nutraceuticals* industry, while smaller in scale, is also currently on a sustained growth path. The success of the food sector has flow-on implications for sectors like in-bound tourism and the growth of Food and wine destination regions like Hawke's Bay, Marlborough and Martinborough.[10] Eight leading producer in this sector (e.g. Seeka Kiwifruits; Turners & Growers and Comvita Limited) are analysed for their productive efficiency in this report.

The Chemical and plastic sector is strong consisting of subsidiaries of most of the world's major companies as well as a large number of very small locally based companies supplying speciality Chemicals or working in niche markets[11]. In total, the sector is still very small by global standards. New Zealand has companies manufacturing a vast range of chemicals for domestic and industrial use. New Zealand also boasts one of the largest methanol production plants in the world. Chemical manufacturing is complemented by associated products: petroleum and related products; polymeric, metallic, and ceramic materials; pharmaceutical, veterinary, and specialised biological products. Plastics companies are also very strong, providing packaging solutions for the dairy, meat and horticultural sectors, and agricultural products. Leveraging off New Zealand's world-renowned agricultural sector, this country's chemical engineering companies are experts in converting primary agricultural-based or forest-based resources into consumer products. These include chemicals for the dairy sector, animal by-products, food processing sectors, wood pulp

[8] Data and information for this Section of the Report were taken from reports and information provided by the Central Bank of New Zealand, the Reserve Bank of New Zealand.

[9] These statistics were taken from *Smart Food, Cool Beverage: New Zealand's Future in the Food and Beverage Sector* produced in 2006 (August) by the Food and Beverage Taskforce, New Zealand and ***Future Directions in Research Relating to Food Security***, A consultation by the biotechnology and biological sciences research council (bbsrc1) on behalf of the research councils.

[10] See *Future Directions in Research Relating to Food Security*, A consultation by the biotechnology and biological sciences research council (bbsrc1) on behalf of the research councils.

[11] The sources from which much of this information has been taken include reports on the New Zealand Chemicals and Plastics Industries from Market New Zealand, New Zealand's economic development agency which is part of New Zealand Trade & Enterprise Department.

and paper sectors and refined plant products. Firms in the plastics sector have collectively doubled their export sales in the last five years, and increased overall turnover by 50 percent. Unlike similar sectors overseas, the plastic sector in New Zealand is strong in processing (polymer resins are not manufactured), with comparatively more packaging produced in New Zealand. This sector produces 113,000 tonnes of packaging, 60 percent of its total plastics processing, connected with primary sector exports (meat, dairy, and horticultural). Three leading firms (Botry Zen Ltd, Cer Group Ltd and Nuplex Industries) are analysed in this report.

Singapore (SG)

Singapore hosts many of the world's major banks, with a number of banks setting their regional office in Singapore for Asian operations.[12]. There are 114 banks registered in Singapore of which about 108 are foreign banks. This sector employs about 60,000 workers. In addition to the three largest domestic banks (DBS, UOB and OCBC) and a dozen others were recently allowed to offer full banking services (e.g. HSBC, CitiBank, MayBank) to the domestic retail market, the remainder offers only corporate or wholesale services, or serves the Asian Dollar market. Total assets of banks in Singapore in 2009 amounted to almost US$500bn. Singapore's capital and bond markets remain significant in global terms while the level of Forex activity in Singapore is one of the largest in the world after the major centres of London, New York and Tokyo. Singapore is also regarded as Asia's premier asset management centre with total assets under management of over US$700bn. Six leading domestic institutions (DBS, UOB, OCBC, Hong Leong, Nomura and Singapura) are analysed for their productive efficiency in this report.

The Food Processing sector in Singapore is rather unique, with around 700 companies, ranging from subsidiaries of the major global Food companies (Nestle, Unilever, Procter & Gamble, Kraft, Tate & Lyle, Cadbury's etc) to a large number of small companies producing largely for the local market. Virtually all inputs to the sector are imported, but this sector accounts for about 3% of manufacturing output and around 5% of employment in manufacturing[13]. Approximately 50% of processed food is exported. The main markets are Japan, USA, Malaysia and China with 63% of exports going to Asian markets and a further 10% to the USA. The remainder are sent to Europe and Australasia.[14] This sector is technologically advanced and benefits from Singapore's reputation for strong hygiene requirements and the emphasis on high quality and safety in its production. It has also carved out niche strengths in the seafood area. Twenty three leading domestic producers - including Oriental Food Holdings; Super Coffeemix; and Cerebos Pacific Ltd listed on the Singapore Stock Exchange - are included in this investigation of productive efficiency.

The Chemicals sector in Singapore accounts for almost 40% of total manufacturing output, and employs only 6% of the manufacturing labour force.[15] Petroleum accounts for approximately

[12] The main sources of information in this section are the Monetary Authority of Singapore and Singapore Official Statistics.
[13] These data were provided in Singapore's *Yearbook of Manufacturing Statistics* 2009.
[14] These data were taken from *Trends & Prospects of the Singapore Food, Beverages & Tobacco Industries*, SMA Industry Study Series 2004.
[15] This information is provided in Singapore's Annual Economic Survey (*Principal Statistics of Manufacturing by Industry Cluster*), 2008, from the Ministry of Trade and Industry.

60% of its output; petrochemicals 30%; and speciality chemicals 10%. Most of the world's leading Chemicals companies operate from Singapore: namely Shell, BASF, Du Pont, Mitsui Chemicals and Exxon Mobil. Shell and Exxon Mobil have further committed to the location with significant recent investments in crackers for Ethylene with output expected to double to approx 4mn tonnes by 2012.[16] Closely related to this sector, Singapore's pharmaceuticals and bio-medical engineering sector is also globally significant accounting for a further 8% of her manufacturing output. The latter sector is much more important in terms of value added providing over 22% of manufacturing value added compared with the 10% of manufacturing value added accounted for by the Chemicals sector. The bio-medical engineering sector (including pharmaceuticals) also accounts for only 3% of manufacturing employment. Five domestic companies - Ap Oil International, Iconic Holdings, Matex International Ltd, Megachem Ltd and Rotol Singapore - operating in the chemical sector are investigated in this report.

Republic of Ireland (IE)

The Banking sector in the Republic of Ireland has expanded rapidly over the past decade on the back of a very strong growth of the Irish economy until recently. By 2008, there were over 42,000 employed in traditional retail banking operations to international banking in Dublin. Over half of the world's top 50 banks had opened operations in the country and total assets held in this sector amounted to €350bn.[17] In total, financial services accounted for around 10% of the country's GDP, one third of all exports of services, and employed almost 90,000 people. However, this sector has been badly hit by the global credit crunch with the country's economy experiencing "depression" conditions, It is uncertain at the moment exactly what impact these events will have on the Irish Banking sector but it is safe to say that the sector will emerge somewhat diminished, with Ireland's reputation as an international Banking centre particularly badly affected. Retail Banking in Ireland is dominated by the "Big 4" banks, Allied Irish Bank, Bank of Ireland, National Irish Bank (owned by Danske Bank), and Ulster bank (owned by RBS). Employment in the retail banks amounted to 31,000 in 2008 working in over 950 head office, regional offices and branches throughout the country.[18]

The Chemicals sector has close to 500 companies ranging from subsidiaries of global Chemicals/pharmaceutical companies (BASF, Pfizer, GSK, Wyeth etc) to smaller speciality Chemicals and plastics producers. Approximately 25,000 are employed in the Chemicals/ Pharmaceutical sector with a further 10,000 in plastics and rubber.[19] The Irish government have successfully pursued policies of attracting global pharmaceutical companies to the Republic, and

[16] See *Chemicals Facts & Figures, Chemicals Factsheet*, produced by Singapore's Economic Development Board, 2009 from which much of the following information is taken.
[17] Much of this information is provided by Financial Services Ireland, an association of over 180 financial institutions - including banks, building societies, insurance companies, fund administrators and managers, investment companies, leasing companies, stockbrokers, treasury companies and other providers of financial services. Established in 1984, the association is a constituent part of IBEC.
[18] These data are available on-line provided by the Irish Banking Federation, in its Banking Statistics.
[19] These statistics are taken from the annual Census of Industrial Production, Central Statistics Office, Ireland, 2007.

currently 16 of the top 20 global pharmaceutical companies have facilities in Ireland.[20] Chemicals and pharmaceutical account for a very important share of Irish foreign trade providing approx 45% of total Irish exports (amounting to almost €45bn in 2008) of which around half were Chemicals and half pharmaceuticals[21]. However, there is no public data on the FDI's operations in the Republic.

The Food and drink sector forms a crucial part of the Republic's economy accounting for approx 8% of total GDP and around 18% of total GVA in manufacturing.[22] It is the single largest indigenous sector in Ireland. Total sales in 2008 amounted to almost €25bn while almost half of exports (over €8bn) went to the UK. There are over 600 companies in the sector employing over 43,000 people. The sector takes virtually all the output of Ireland's 120,000 farmers and taking into account distribution and retail, in total over 230,000 people are in some ways dependent on the sector in Ireland.[23]The sector's strengths are linked to the traditional areas of meat and dairy but increasingly prepared Foods have become an important sector now accounting for around half of total sales. The Republic is the single largest supplier of Food to the UK and the biggest exporter of lamb to the EU. It also produces 15% of global output of infant formula milk.[24] The sector comprises Irish subsidiaries of global producers such as Unilever, Cadbury, Heinz, specialised manufacturers such as Nutricia, and large locally based companies. Five major locally based food producers, including Kerry Group, Greencore Group, Donegal Creameries, are analysed for their productive efficiency.

3. Efficiency Concepts

The purpose of this section is to introduce some important efficiency concepts underlying this report. Measuring scale and technical efficiencies amongst a group of companies, as the chosen research method in this investigation, is conceptually easiest if firms use only one input and produce one output. A ranking of the ratio of output to input would provide a good guide to comparative performance. However, when firms more realistically use multiple inputs and outputs single ratio, the analysis is more difficult to construct and interpret. In such instances, Data Envelopment Analysis (DEA) is a means of measuring efficiency and produces a single measure of efficiency for each firm which lies between 0 (meaning the firm is totally inefficient) and 1. Data Envelopment Analysis is generally used to measure technical efficiency, scale efficiency and improvements in efficiency over time – the latter referred to as Total Factor Productivity. These three terms provide the analytical backdrop to DEA and deserve definition:

[20] This information is provided on-line by PharmaChemical Ireland an association of approximately 50 companies. PharmaChemical Ireland is a major sector within IBEC.
[21] As reported in *Trade Statistics of Ireland*, produced by the Central Statistics Office, Ireland.
[22] For detailed information see *Food and Drink Industry in Ireland: Competitiveness Indicators 2009* published by IBEC, the Irish Business and Employers Confederation.
[23] See the *Census of Industrial Production*, produced by the Central Statistics Office, Ireland.
[24] See *An end-to-end strategy for the Irish Food and Drink sector Economic impact and policy challenges*, a report commissioned by Food and Drink Industry Ireland, and published by IBEC, 2006.

Technical efficiency - a measure of how efficiently inputs are converted into outputs. A firm is said to be technically efficient if it produces a given set of outputs using the smallest possible amount of inputs.

Scale efficiency - a measure of a firm's size relative to the minimum efficient scale. The minimum efficient scale refers to a conceptual size of firm where costs could be minimized. A firm is said to be scale efficient if it operates on a scale that maximises productivity (which may require increasing or decreasing the scale of production to take best advantage of available technology).

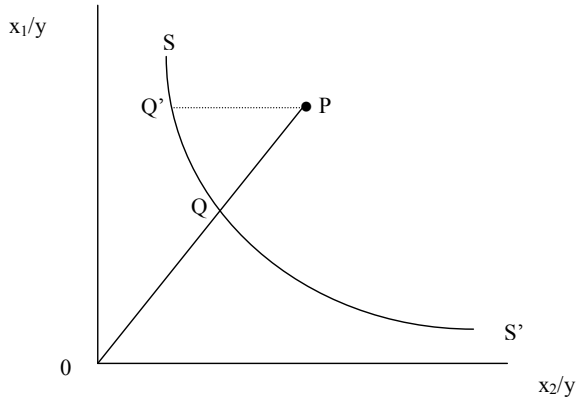
Total Factor Productivity is the improvement in best practise year on year, taking comprehensive account of all inputs and outputs.

Modelling Efficiency:

The discussion begins with an examination of Farrell's (1957) approach to efficiency modelling, before moving onto to a discussion of how efficiency can be empirically measured using data envelopment analysis. Farrell (1957) proposed a framework for understanding efficiency. Farrell's approach examines a single firm which has access to two factor inputs x_1 and x_2, which are used to produce an output Y. If the best practise conversion of inputs into outputs is known, then a measure of the firm's technical, or productive efficiency can be gained.

Farrell (1957) assumed that the best practice was known and is defined by the most technically efficient isoquant. This illustrated in Figure 6 as the isoquant SS'. If the firm under analysis achieves a level of output Y from using inputs x_1 and x_2, then this can be depicted as point P. Since point Q lies on the most technically efficient isoquant, then the technical inefficiency of the firm is distance QP. That is, the firm could achieve the same level of output, Y, at Q, using less of the inputs x_1 and x_2.

Figure 6: Technical Efficiency



Empirical studies generally state the measure of inefficiency in percentage terms and so the ratio QP/0P becomes useful. Since efficiency is the converse of inefficiency, then efficiency is simply 1 – (QP/0P), or 0Q/0P. The approach exhibits a number of important characteristics.

Farrell's efficiency approach is radial. As such, all improvements in efficiency must exhibit a proportionate decrease in the inputs of x_1 and x_2. Inputs are continuous in nature, not indivisible or discrete. As such, it is not possible to compare P with Q', where x_2 can be reduced, but x_1 must be held constant.

Farrell's approach assumes constant returns to scale. If variable returns are considered, then *productive efficiency* and *scale efficiency* need to be captured. We will return to this in the next sub-section.

The efficiency approach can have an input or output orientation. In the preceding discussion we have used an input orientation. Firms reduce inputs in order to boost efficiency. Under an output orientation, firms increase outputs (for a given sue of inputs) in order to boost efficiency. These perspectives should be seen as two sides of the same coin.

Under a model of constant returns to scale, the input and output orientation provides identical measures of efficiency. Under an assumption of variable returns to scale the approaches produce different answers. Empirical researchers are generally advised to adopt an orientation which best reflects the firms' locus of control, that is, is it more likely that the firms are able to control inputs or outputs? Farrell (1957) assumes that the most efficient technology is known. In reality this is not the case and the most efficient technology needs to be derived from the sample. Farrell (1957) went on to propose two approaches, one based on non-parametric techniques which envelops the data with a linear – piecewise frontier; and another which uses parametric techniques to again envelop the data with Cobb-Douglas production frontier. The underlying rationale behind both approaches is that the most efficient firms within the sample define the most efficient technical isoquant SS'. Therefore, the measure of efficiency is within sample; and researchers need to be aware that the results may suffer from the exclusion of more efficient firms.

The non-parametric approach has a number of appealing features. In particular, unlike the parametric approach, there is no requirement to assume a functional form for the production function. More importantly for this investigation, parametric techniques require large sample sizes in order to be statistically robust. In contrast, non-parametric techniques can produce robust results even when the sample size is small. This investigation examines the efficiency of a small number of companies within oligopolistic sectors. Therefore, we employ a non-parametric technique. The technique is known as data envelopment analysis, DEA; and is discussed in detail within the next section.

Measuring Efficiency

As outlined above, the simplicity of ratio analysis breaks down as the problem under investigation becomes more complex. Firms using one input and producing one output can be

examined numerically and graphically, so can firms with two inputs and one output, as in Figure 6. Once the production scenario becomes multi-faceted with numerous inputs and outputs, then a more complex approach is needed. A suitable approach is DEA. Charnes, Cooper and Rhodes (1978) developed DEA.[25] The approach follows the work of Farrell (1957) and provides a measure of productive efficiency when considering the conversion of multiple inputs into multiple outputs.

We begin with N firms. Each firm produces M outputs with K inputs. For a given firm *i*, the vector of outputs is y_i and the vector of inputs is x_i. For the entire sample the matrix X, (K x N), is the matrix of inputs; and Y, (M x N), is the matrix of outputs. The Charnes et al. (1978) approach seeks to provide each firm the best possible efficiency score. So using the ratio approach, the efficiency of each firm $u'y_i / v'x_i$, needs to be maximized relative to all other firms, where *u* and *v* are weights to be estimated. The weights are found using a linear program:

$\text{Max}_{u,v}\ (u'y_i / v'x_i)$

Subject to $u'y_j / v'x_j \leq 1$ j = 1,2,….N; u, v ≥ 0

This approach ensures that the values for efficiency lie between 0 and 1. However, the approach also has an infinite number of solutions. This problem can be managed by including the linear constraint $\nu\, x_i = 1$.

$\text{Max}_{u,v}\ (u'y_i)$

Subject to $\nu\, x_i = 1$; $\mu'y_j - v'x_j \leq 0$ j = 1,2,….N; u, v ≥ 0

This provides the multiplier form of the linear program. Using the concept of duality the envelopment form, (with fewer constraints than the multiplier form) can be derived:

$\text{Max}_{\theta,\lambda}\ \theta$

Subject to $-yi + Y\lambda \geq 0$; $\theta xi + X\lambda \geq 0$; $\lambda \geq 0$

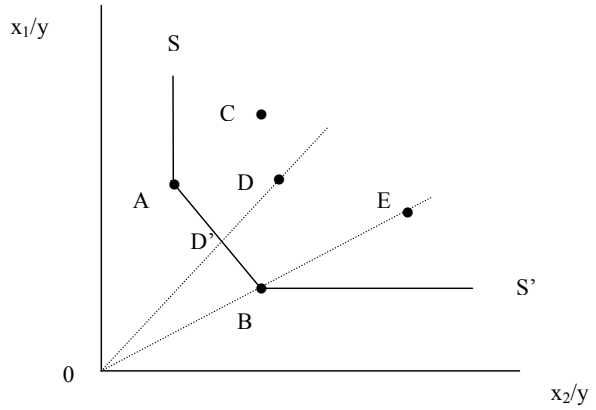
θ is now a scalar measure of efficiency. The linear program is run N times, once for each firm, generating a θ for each firm. When the program is run for firm *i*, then all other firms within the sample can form the efficient frontier. The selection of the weights λ determines which sample firms are peers against which firm *i* should be assessed. If the value of λ for a given sample firm is zero, then it is not a peer of firm *i*.

Figure 7 illustrates DEA and contains observations on five firms: A, B, C, D and E. The linear-piecewise frontier is created by the two most efficient observations, A and B. This frontier provides the empirical representation of the most technical efficient isoquant, SS'. Since E lies on a radial expansion of point B, then B is the peer of E. The efficiency of E will be measured relative to B. When assessing E's efficiency, the λ for all observations, other than B, will be 0. In contrast, D does not lie on a radial expansion of a point, (A or B), which defines the efficient frontier SS'. The

[25] For an introduction to DEA see Coelli (1996).

peer for D, is D' which is a composition of A and B. The values for λ will then represent the weights of A and B in the composite reference point D' for firm D.

Figure 7: Linear Piecewise Frontier



Scale Efficiency

The foregoing discussion assumes constant returns to scale. Without a consideration of scale effects, measures of technical efficiency may well be compounded by scale inefficiencies. An approach which splits scale and technical efficiency is important, not only for providing a more accurate measure of efficiency, but for highlighting the potential to achieve efficiency gains through the pursuit of minimum efficient scale, or by improving technical efficiency at the current level of scale. Banker, Charnes and Cooper (1984) proposed a data envelopment model capable of accommodating variable returns to scale. The model only differs from the previous approach of Charnes et al. (1978) by including the constraint $\Sigma\lambda = 1$.

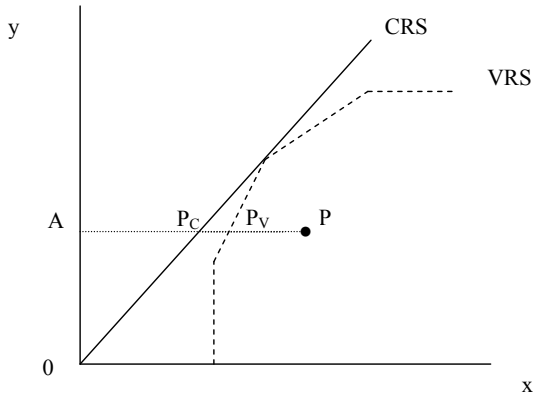
Max $_{\theta, \lambda}$ θ

Subject to $-yi + Y\lambda \geq 0$; $\theta xi + X\lambda \geq 0$; $\Sigma\lambda = 1$; $\lambda \geq 0$

The impact of this additional constraint is to make the frontier more convex and envelop the data more tightly. This increases the technical efficiency scores. If variable returns are important, then the results for technical efficiency from the constant returns to scale and the variable returns to scale models will be different; and the measure of scale inefficiency will be equal to the difference between the two. These ideas are illustrated in Figure 8.

Figure 8 presents the constant returns to scale frontier, CRS, and the VRS frontier, VRS, for a firm with one input x and one output y. Technical inefficiency under CRS is the distance PP_C, while under VRS technical inefficiency is PP_V.

Figure 8: Constant and Variable Returns



Given that at the minimum efficient scale, returns to scale are constant, then it follows that scale inefficiency is the distance P_VP_C. In ratio form:

Technical efficiency (CRS) $= AP_C / AP$

Technical efficiency (VRS) $= AP_V / AP$

Scale efficiency $= AP_C / AP_V$

Therefore, Technical efficiency (CRS) = Technical efficiency (VRS) x Scale efficiency

Because, Technical efficiency (CRS) = $AP_V / AP \times AP_C / AP_V = AP_C / AP$

In summary, technical efficiency (CRS) is a combination of pure technical efficiency and scale efficiency.

Efficiency Changes – Total Factor Productivity & Malmquist Index

The preceding discussion has covered the measurement of efficiency in a single time period. By introducing Malmquist indices into the analysis it is possible to measure efficiency changes over time. Between different time periods, firms have the opportunity to improve their productivity in a number of ways. First a firm can improve its technical efficiency. The firm achieves this by moving nearer to the best practice frontier. Similarly, a firm can improve its scale efficiency by moving nearer to the minimum efficient scale. It is also possible that the best practice frontier can improve. Such a change is referred to as technological gains. The sum of technical, scale and technological gains is *Total Factor Productivity*, TFP.

DEA can be used to measure TPF, as well as the underlying changes in technical, scale and technological efficiencies. This requires the use of a number of separate linear programs, where the output of each program is fed into the calculation of Malmquist indices, as proposed by Fare *et al.* (1994).

$$m_0(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{d_0^t(X_{t+1}, Y_{t+1}) \times d_0^{t+1}(X_{t+1}, Y_{t+1})}{d_0^t(X_t, Y_t) \times d_0^{t+1}(X_{t+1}, Y_{t+1})} \right]^{\frac{1}{2}}$$

where m_0 represents the productivity of point (X_{t+1}, Y_{t+1}) relative to (X_t, Y_t). Since, this change in productivity from time period t to t+1 can be measured going forward or backward in time, m_o is a geometric mean of the two approaches. If the value for m_o is greater than one, then productivity growth has been positive, and if it is found to be less than one the growth has been in decline.

The linear programs required to estimate m_0 are described in Coelli (1996) and are contained within a number of DEA software packages.

Data and Sample

The use of DEA requires the collection of data on inputs X and outputs Y. The identification of inputs and outputs clearly needs to accord with the production processes used in each sector.

Data on Chemical sector and Food sectors within the Northern Ireland region are obtained from the Northern Ireland Annual Business Inquiry, whilst data for the other economies is obtained from Datastream. Companies were selected if they fell within the standard industrial classifications SIC 15 (Manufacture of Food and Beverages) and SIC 24 (Manufacture of Chemicals and Chemical Products). The inputs are generally the capital stock of the company and all other cash expenses. These cover the main generic inputs of capital, labour and raw materials purchases in manufacturing. Total Revenues is used as the measure of output. The benefit of this measure is that it is widely available within published accounts and is related to total production activities[26]. As two databases are used, there are minor differences in the treatment and operationalisation of data[27] . The data for these sectors in Northern Ireland relates only to those companies who participated in the Northern Ireland Annual Inquiry. Extrapolations to non-participant companies are not used in this investigation and the data were provided by the DETI Statistics with the names of companies removed.

[26] However, total revenue is a combination of total production and prices. By including price within the measure of output, there is a risk that technical (production) efficiency can be biased if a company is better, or worse at pricing than its rivals. The extent to which this risk is a concern depends upon the degree of price competition and differentiation in the sector and firms under consideration. Less differentiation and greater homogeneity should result in stronger price competition. This in turn should drive convergence not only in pricing, but in the underlying production technologies used by each firm.

[27] Revenue is taken as the net revenue line in Datastream. Capital is taken as net property, plant and equipment. All other cash expenses is taken as the difference between net revenue and earnings before interest, tax and depreciation. All data was converted into UK Pounds sterling using Purchasing Power Parity exchange rates published by the International Monetary Fund. From the Northern Ireland Annual Business Inquiry, Revenue is Total Turnover (399); all other cash expenses is Employment Costs (450) + Total purchases of energy, goods, materials and services (499). Net Capital Expenditure is Acquisitions (600)-Disposals (699). Importantly, the Northern Ireland data on capital is a flow, not a stock measure, as in the Datastream data. This is due to data limitations and the working assumption is that net capital expenditures act as a positive proxy for net capital stock. (i.e. the more capital stock a company has, the more capital expenditure it will undertake to replace, repair and maintain).

Datastream only provides data on all publicly listed companies. For Singapore and the Republic of Ireland, [28] data included companies who operate outside these economies, but seek to access international capital markets by being listed at these locations. All such firms were identified by examining their business summary reports on the *BusinessWeek* website. Any firm found to be only listed and not trading from a particular economy was excluded from the sample. Data coverage for Food and Chemicals was in part determined by the nature of the available databases. Data sourced from Datastream covers the period 2005 to 2008. Any company with missing data, or only a partial trading history during this period was excluded from the sample. Data from the Northern Ireland Annual Business Inquiry covers the period 2005 to 2007.

Table 1: Data coverage by sector and economy

Banking	N	2000	2001	2002	2003	2004	2005	2006	2007	2008
NI	3	✓	✓	✓	✓	✓	✓	✓		
IE	8	✓	✓	✓	✓	✓	✓	✓		
NZ	6	✓	✓	✓	✓	✓	✓	✓		
SG	6	✓	✓	✓	✓	✓	✓	✓		
Chemical		2000	2001	2002	2003	2004	2005	2006	2007	2008
NI							✓	✓	✓	
IE	0									
NZ	3						✓	✓	✓	✓
SG	5						✓	✓	✓	✓
Food		2000	2001	2002	2003	2004	2005	2006	2007	2008
NI							✓	✓	✓	
IE	5						✓	✓	✓	✓
NZ	8						✓	✓	✓	✓
SG	23						✓	✓	✓	✓

Data on the banking sector is obtained from Bankscope. This database contains bank data across most major economies. The data can be searched by country and city. This enables data for Northern Ireland to be sourced by searching for banks who have registered offices in Belfast and Londonderry. Data on the Banking sector is obtained from Bankscope, covering the period 2000 to 2006. Bankscope provides data up to the year 2008 and, for some banks, goes back to the 1980's.[29] Because of the credit crisis, data from 2007 and 2006 are excluded in order to focus on a period of normal trading activity.

The production function of banks follows the work of Casu and Molyneaux (2003). Output is measured as total loans plus other earning assets. Inputs are deposits plus short-term borrowings; and all other cash expenses. All values are converted into UK Pounds Sterling using the purchasing power parity exchange rates published by the International Monetary Fund. Table 1 provides a summary of the data coverage by sector, economy and year.

[28] There is no chemical company listed on the Republic of Ireland's stock market and hence no data is in the public domain, or within Datastream. This reflects a common problem when examining the Chemical sector, which is dominated at a global level by a small number of firms, with operations in many different economies.

[29] Banking data before 2000 was not collected for two reasons. First, a longer time period can reduce the number of banks with a full trading history throughout the sample period. Second, the purpose of the analysis is to assess recent productivity differences across economies. The relevance of more historic data is therefore less, than contemporary data.

4. Results

Descriptive statistics for each sector, by economy, are listed in Table 2. The statistics relate to the final sample year for each sector, (i.e. 2008 for Chemical and Food; 2006 for Banking). For each of the three sectors, within each economy, the descriptive statistics show a good degree of variability in the outputs and inputs. This variability is especially important for identifying scale efficiencies within the sample. Across all of the sectors and economies there is also evidence of differences in the size of companies. In particular, the minimum and maximum output values across economies for particular sectors differ. When conducting the efficiency comparisons across economies, these differences may also enable the identification of different scale efficiencies between economies.

Tables 1 and 2 list the number of observations within each grouping. Again there are marked differences across the industrial groupings and economies. If the sampling process has correctly identified and collated data on leading companies, then the number of observations may provide an indication of the degree of competition within each sector and economy. It is likely that competition provides firms with incentives to be efficient and the nature of the data may be illuminating in this regard.

Efficiency Results

The efficiency results for each sector are presented in turn. Single frontier results for each country/region are presented first. This part of the analysis provides an intra-country/regional analysis of efficiency. Issues regarding the variability of technical and scale efficiency amongst competing companies within a country/region are examined. Secondly, the pooled efficiency results are presented. This analysis enables an inter-country/regional analysis of productivity. Questions relating to whether a particular sector in a given location has superior efficiency are addressed. Finally, the Malmquist-based results are presented. This analysis provides an understanding of productivity gains over time. The extent of productivity gains and, in particular, which aspects of efficiency, technical, scale or technological have driven overall efficiency gains are considered. We begin with an analysis of Banking.

Table 2: Outputs and Inputs in £millions

Chemical Output - Revenue	NI	IE	NZ	SG
Average	25403		516300	27666
Std Dev	36664		886902	24407
Min	1039		344	445
Max	104493		1540396	53049
n	17		3	5

Processed Food Output - Revenue	NI	IE	NZ	SG
Average	27686	1159159	440886	112511020
Std Dev	52896	1175672	468321	415931456
Min	666	88242	39332	16358
Max	323079	3059333	1170125	1941011610
n	92	5	8	23

Banking Output – Loans and other earning assets	NI	IE	NZ	SG
Average	22955	29220	39306	51762
Std Dev	19563	35009	33951	55263
Min	5088	2326	1506	478
Max	43859	101516	91715	118651
n	3	8	6	6

Chemical Input - Capital	NI	IE	NZ	SG
Average	1005		105920	6152
Std Dev	1594		179663	8651
Min	7		2176	4
Max	5992		313377	21359

Processed Food Input - Capital	NI	IE	NZ	SG
Average	799	227907	101628	204526791
Std Dev	4390	248097	95525	806234233
Min	5	10953	951	1178
Max	42411	629630	264152	3856513401

Banking Input – Deposits and short-term funds	NI	IE	NZ	SG
Average	16708	16368	34992	41422
Std Dev	11532	24411	30174	45198
Min	4921	1789	2008	376
Max	27966	71605	84006	95915

Chemical Input - Other Expenses	NI	IE	NZ	SG
Average	15838		477224	26459
Std Dev	21637		818591	22459
Min	858		1221	1681
Max	82334		1422443	50659

Processed Food Input - Other Expenses	NI	IE	NZ	SG
Average	26351	1065082	393678	46613288
Std Dev	50739	1068418	424239	153107913
Min	455	79880	35873	15756
Max	306968	2782661	1043341	593605292

Banking Input – Other Expenses	NI	IE	NZ	SG
Average	333	270	492	635
Std Dev	205	523	462	702
Min	182	2	45	6
Max	566	1520	1257	1618

Banking Efficiency – Single Frontiers

Figure 9

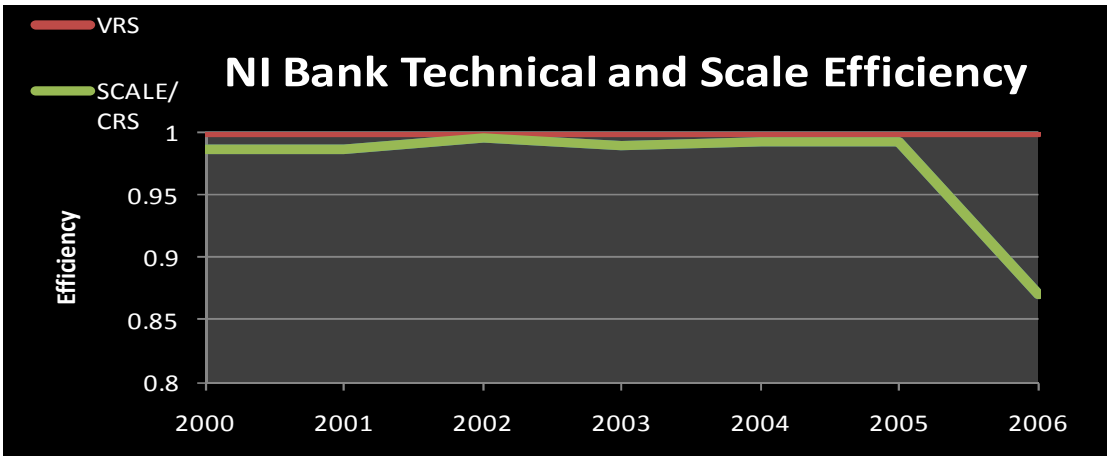


Figure 9 presents the efficiency results for Banking in Northern Ireland. Assuming variable returns to scale, the average technical efficiency scores for the banks are all high and very close to one. This finding indicates that the banks within Northern Ireland all achieve a similar level of efficiency. This finding may be driven by competition or the adoption of production technologies from parent companies in the UK. The scale efficiency within the Northern Ireland sample is high and stable until 2005. The extent of the drop in 2006 is relatively minor. The results for scale efficiency would suggest that most banking groups in Northern Ireland are operating at a similar level of scale.

Figure 10

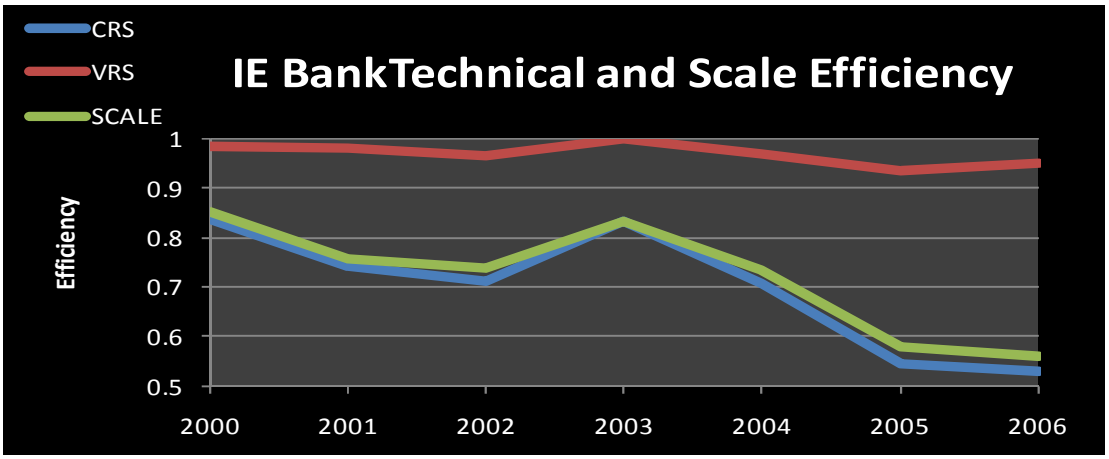


Figure 10 illustrates the efficiency results for the Republic of Ireland's banks. Again assuming variable returns to scale, there is good evidence that all the banks achieve a similar level of technical efficiency and this is relatively constant across the period of the sample. In terms of scale of efficiency, the Republic of Ireland's banks show evidence of a declining trend, falling from

around 80% in 2000, to just under 60% in 2006. The implication of these results is that by 2006, the average Irish banking group could increases scale efficiency by a substantial 40%.

Figure 11

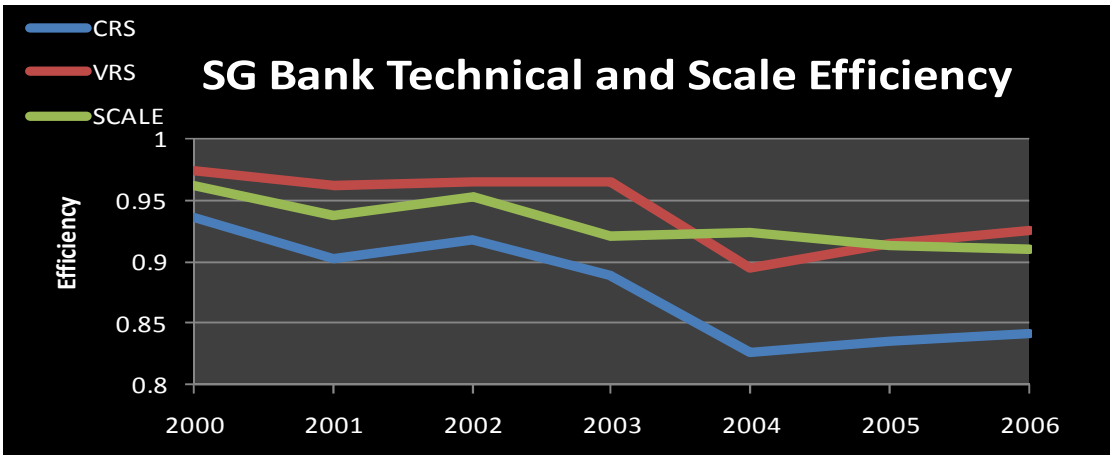


Figure 11 presents data on efficiency within the Singaporean Banking sector. Technical efficiency, assuming variable returns to scale, is marginally below 1 in 2000; and follows a downward trend towards 2006. In 2006, average technical efficiency measures 93%; indicating that the average banking group could keep inputs constant and increase output by 7%. Scale efficiency also declines throughout the period, but the degree of inefficiency is less than in the Republic of Ireland's banking sector.

Figure 12

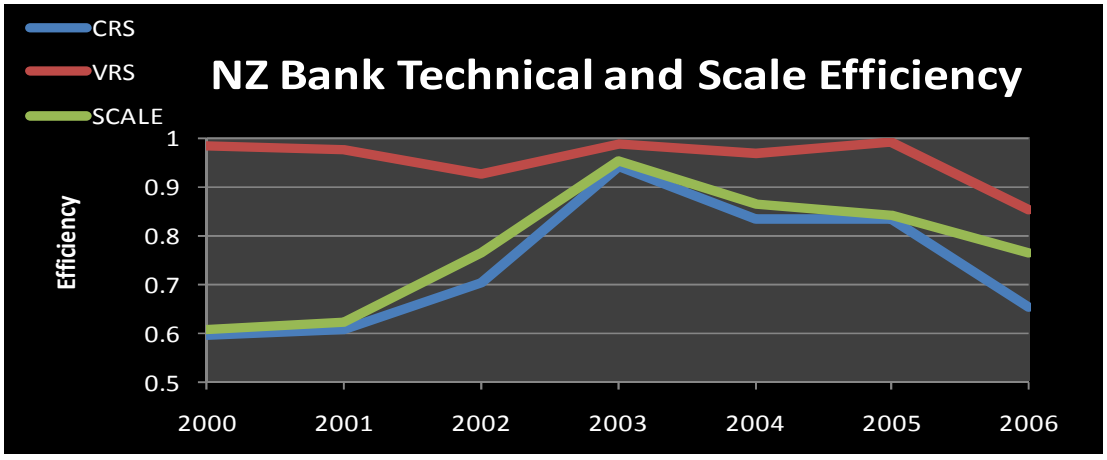


Figure 12 illustrates the efficiency scores for New Zealand's banking sector. On average technical efficiency is high and relatively stable. Scale efficiency was markedly low in 2000; and improved until 2003, when a modest decline was evident.

Across all of the locations, Banking tends to share a high degree of technical efficiency, but instances of weaker scale efficiency. The high degree of technical efficiency is perhaps not that surprising given the relatively homogenous nature of retail banking services and international

banking. Loans and savings are mainly sold on price. Therefore, homogeneity and price competition may act as a strong driver of technical efficiency. Scale efficiency refers both to banks that are too small and too large. So considerations of dominant players, as well as mergers of under scale operations need to be considered carefully by policymakers.

Banking Efficiency – Pooled Frontiers

In order to examine the technical efficiency of banking in Northern Ireland against the three other locations, the data across all locations was pooled. DEA was then re-run and technical and scale efficiencies are compiled for each location.

Figure 13 provides the variable returns technical efficiency scores. Throughout the entire sample period banks within Northern Ireland is found to exhibit the lowest technical efficiency. The Republic of Ireland's banks have the most superior technical efficiency. By 2006, banks within Northern Ireland had technical efficiency scores less than 40%, whereas in the best performing location, banks in the Republic of Ireland has managed an average technical efficiency of around 90%. Banks in Singapore followed a similar trend as the Republic, and has managed an average technical efficiency of around 80%.

Figure 13

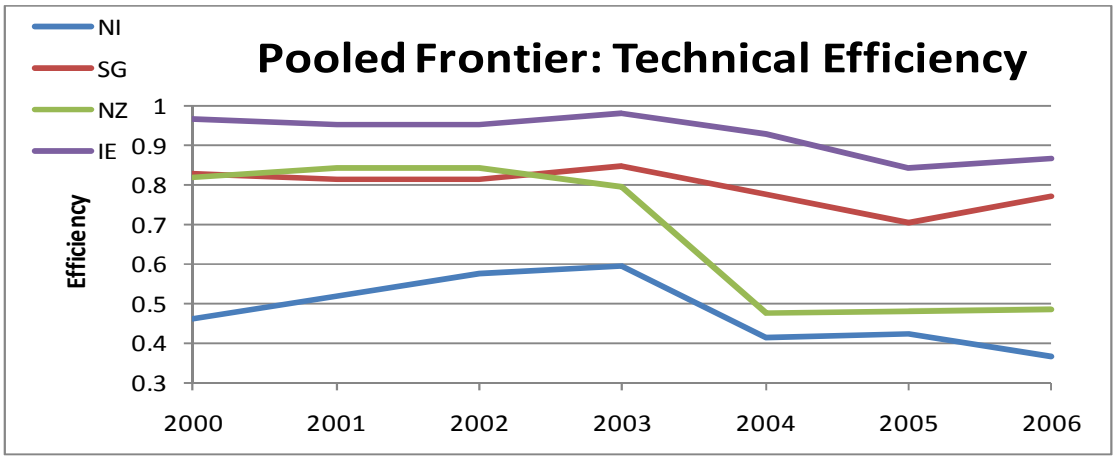
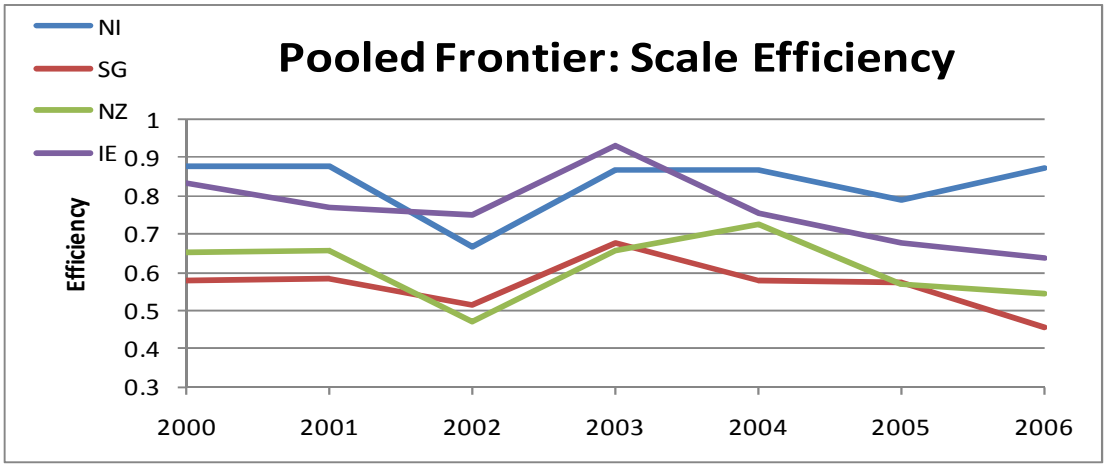


Figure 14 illustrates scale efficiency for each location. In marked contrast to the technical efficiency results, banks within Northern Ireland have predominately exhibited the strongest scale efficiency. Taken together, the results indicate that when examining the four locations, banks in Northern Ireland are closest to the minimum efficient scale, but technical efficiency is poor. A much higher level of output is possible with the current level of factor inputs employed within the sector.

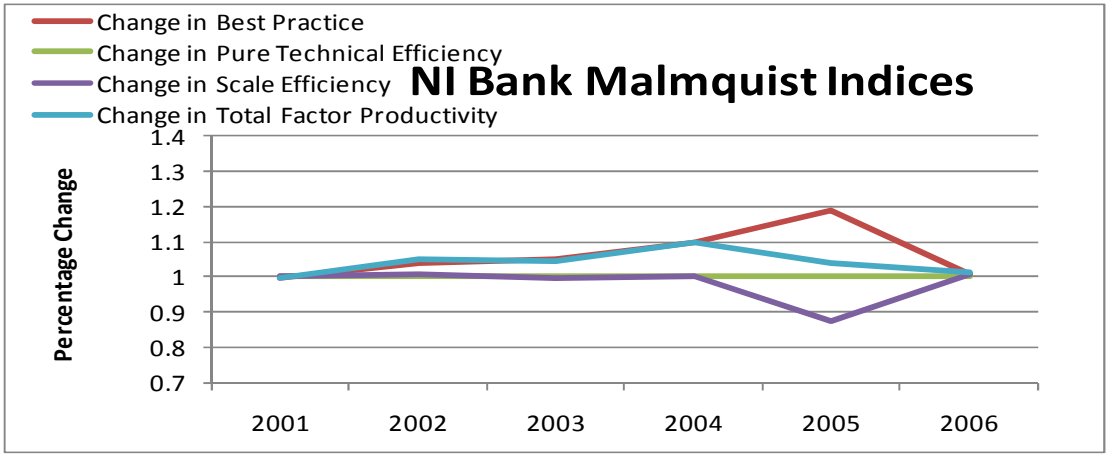
Figure 14



Banking Efficiency - Malmquist Indices

Figure 15 provides data on the development of efficiency over time. Throughout the period Total Factor Productivity remained positive and on average banks in Northern Ireland managed a compound productivity growth rate of 4%. This was mainly driven by technological change i.e. each year the best practice frontier continued to improve. Improvements in scale and technical efficiency were minimal.

Figure 15



Efficiency development in the Republic of Ireland's Banking sector is depicted in Figure 16. On average, banks in the Republic of Ireland managed to improve Total Factor Productivity by 3.7% per annum. In the main, these gains were driven by technological improvements in 2004 and 2005, where the best practice frontier improved by more than 30%. Improvements in scale and technical efficiency were minimal.

Figure 16

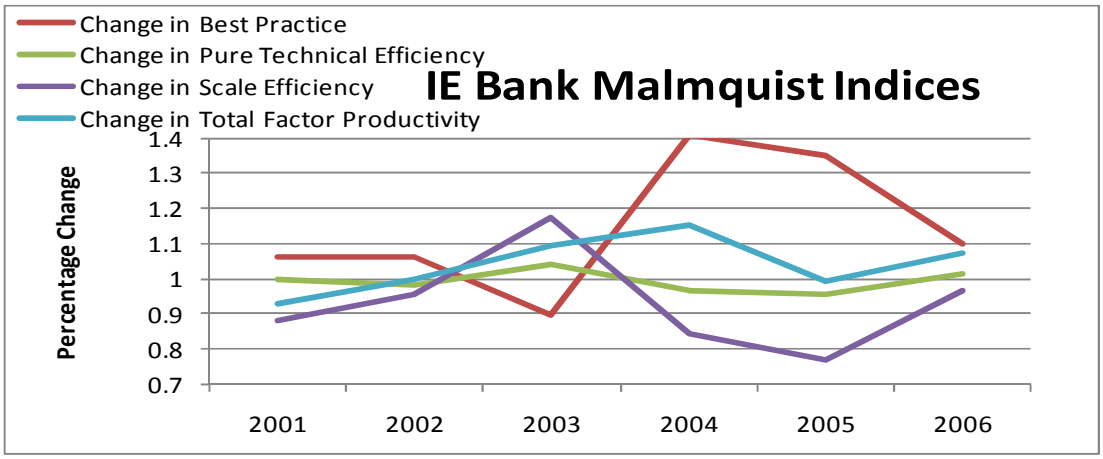


Figure 17

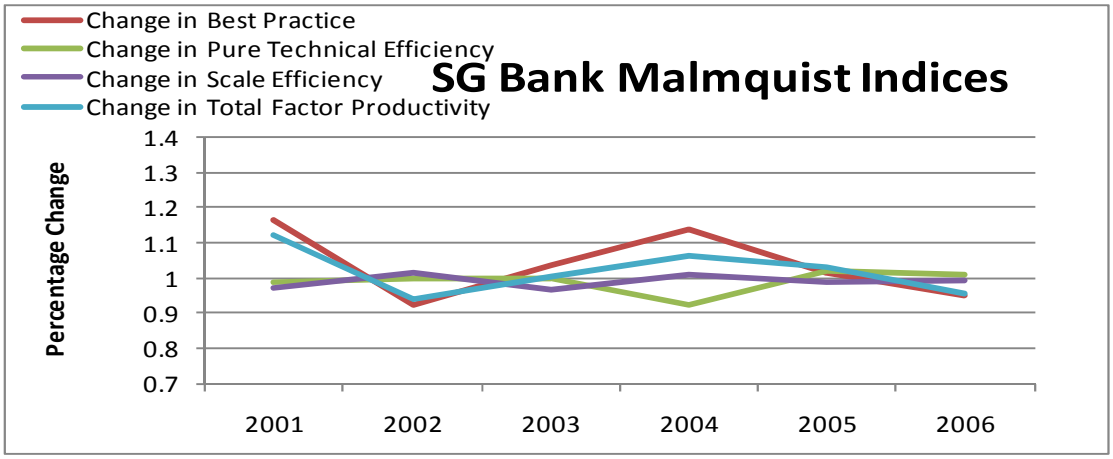
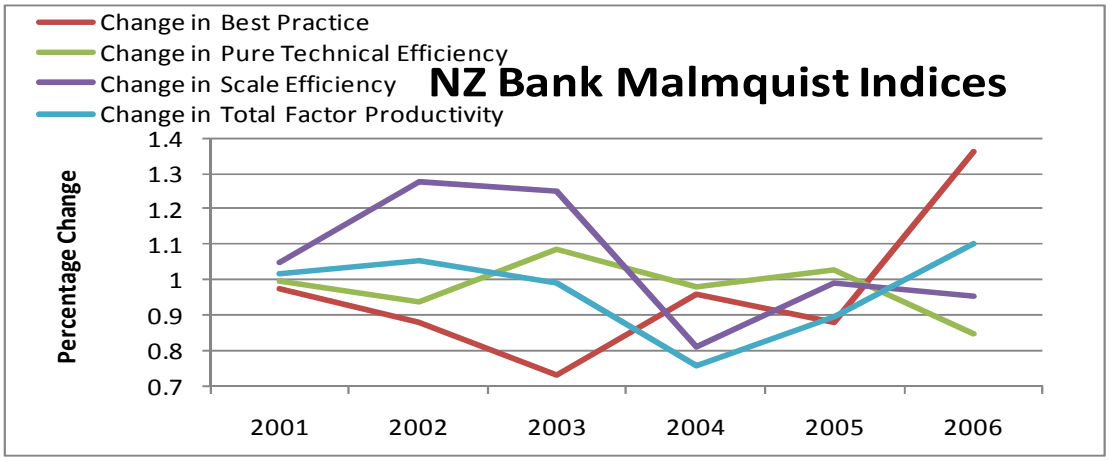


Figure 18



Malmquist results for Singapore are presented in Figure 17. Over the period Singapore banking only managed to improve productivity by 1.6% per annum. Throughout the time period there is weak development of technical, scale and technological efficiencies. The results for New

Zealand are presented in Figure 18. Despite marked improvements in scale efficiency in 2002 and 2003, the New Zealand Banking sector failed to improve Total Factor Productivity over the entire period. On average productivity declined each year by around 4%.

Summary – Banking

The intra-sector analysis shows that banks in Northern Ireland have a high degree of technical and scale efficiency. The Malmquist analysis shows that between 2000 and 2006 the Northern Ireland's banking sector achieved an annualized productivity growth rate of 4%. No other banking sector within this investigation bettered this growth rate. In addition, when compared with the Republic of Ireland, Singapore and New Zealand, banks in Northern Ireland have superior scale efficiency. Taken together, these results suggest that Banking within Northern Ireland has strong efficiency characteristics.

The only clear area for concern is the strong degree of technical inefficiency exhibited by the Northern Ireland's banking sector, when compared against all other regions. A possible explanation for the degree of technical inefficiency may be found in the nature of the Northern Ireland's banking sector. On one level the geography and distribution of the population within Northern Ireland may result in a relatively expensive network of branch banking in retail. This would not be unique to Northern Ireland and has been found to be the main reason behind a productivity difference between French and Spanish Banking, for example (see Dietsch and Lozano-Vivas, 2000). Another explanation may be more qualitative and represent the nature of banking business undertaken within Northern Ireland. For example, banking with Singapore and Ireland may be more closely associated with large multinational enterprises seeking access to debt and equity financing. This type of banking is very different to that required within Northern Ireland and therefore a comparison with Singapore, in particular, may not be that reasonable. In Figure 13, which illustrates the pooled technical efficiency scores, Northern Ireland tracks New Zealand most closely. If New Zealand is taken as a more reasonable comparator for Northern Ireland's banks, then towards 2006, Northern Ireland has achieved a good level of technical efficiency.

Chemical Efficiency – Single frontiers

Scale efficiency within Northern Ireland's chemical sector is high and averages above 90% throughout the sample period as indicated in Figure 19. Assuming variable returns to scale, the average technical efficiency is lower, averaging around 82%, but this is still a reasonably high level of technical efficiency.

Technical and scale efficiency for Singapore's chemical sector is presented in Figure 20. Assuming variable returns to scale, the technical efficiency, on average, is high and improving. Scale efficiency is also reasonably high, starting at around 85% in 2005; and improves throughout the time period to just under 95%.

Figure 19

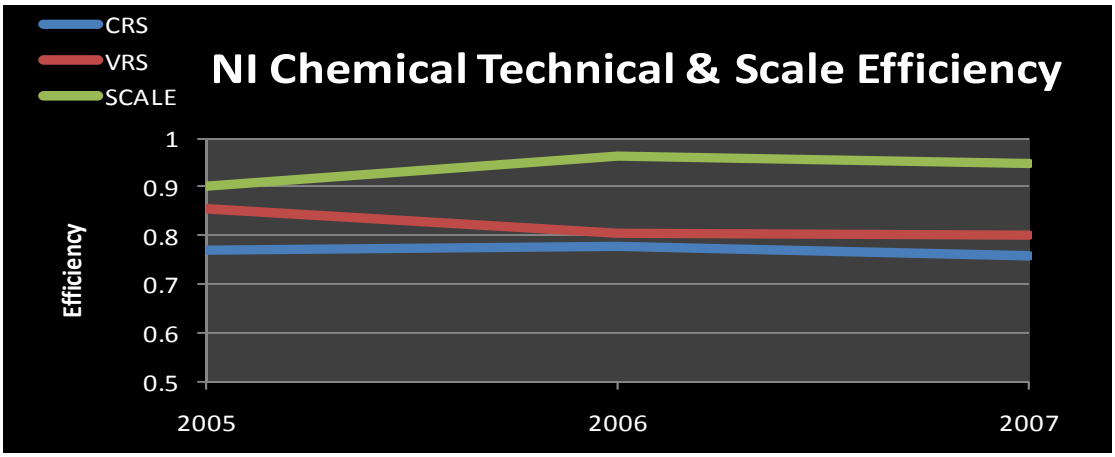


Figure 20

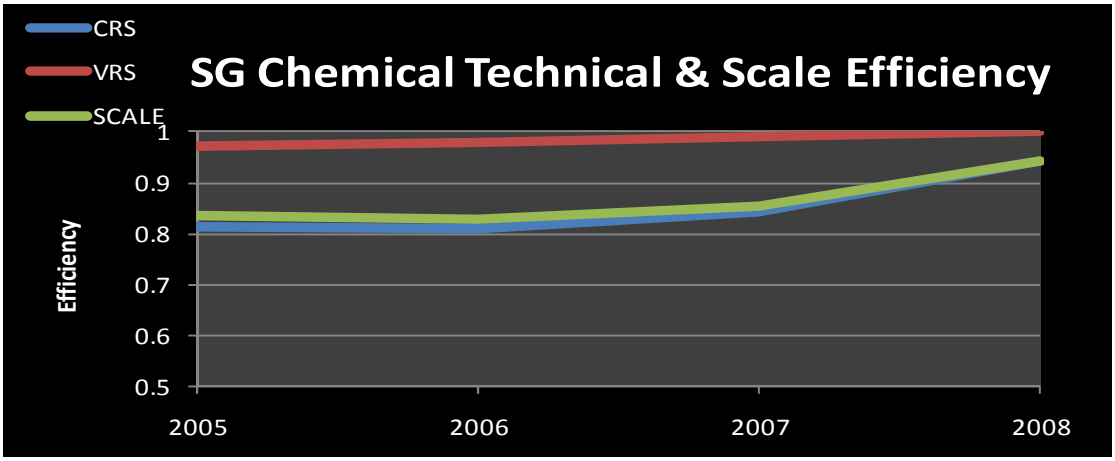


Figure 21

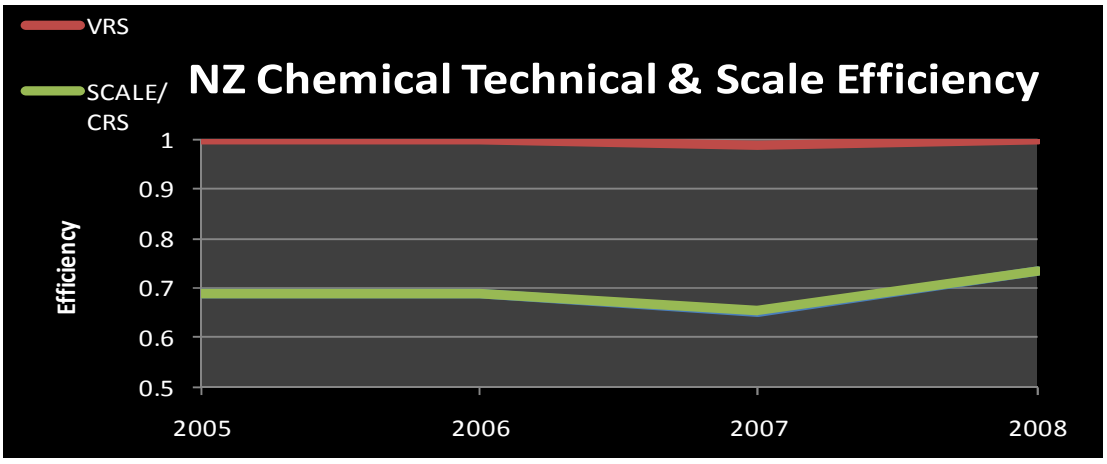


Figure 21 provides the technical and scale efficiency for the New Zealand Chemical sector. Again assuming variable returns to scale, technical efficiency is close to 100% throughout the data

period. Scale efficiency is markedly lower at around 70%, suggesting that a number of firms are either too large, or too small, relative to the minimum efficient scale.

Chemical Efficiency – Pooled Frontiers

In order to assess the technical efficiency of the chemical sector in Northern Ireland against the other locations, the chemical sector data across all locations was pooled. DEA was then re-run and technical and scale efficiencies compiled for each location.

When compared with New Zealand and Singapore, the Chemical sector in Northern Ireland is comparably efficient. The technical efficiency, illustrated in Figure 22 is slightly below 80%. This level of efficiency is on a par with New Zealand and markedly better than Singapore.

Figure 22

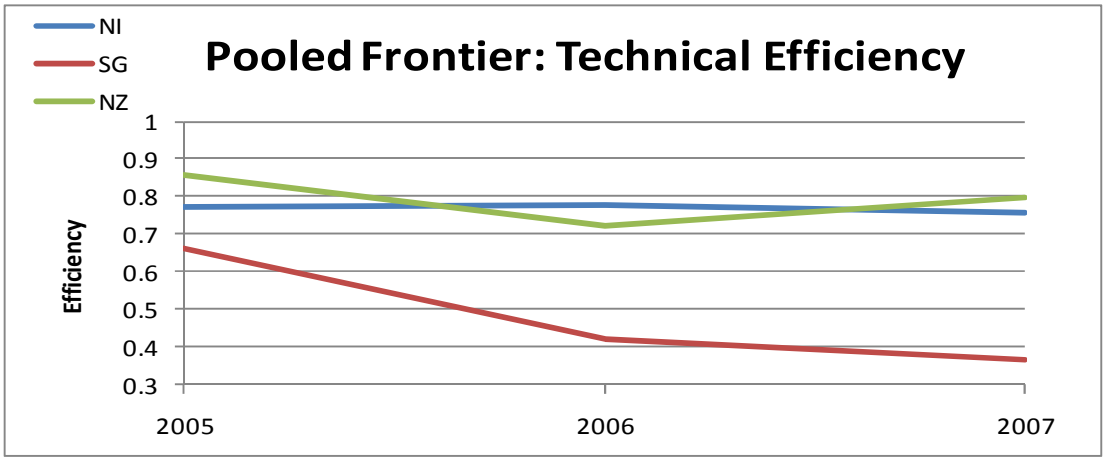
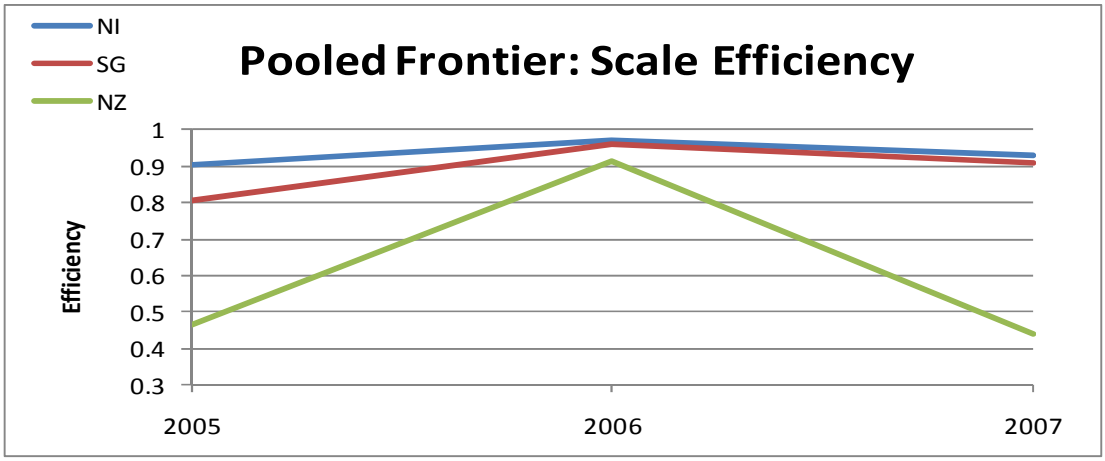


Figure 23



Scale efficiency is presented in Figure 23. Again Northern Ireland performs favourably when compared with Singapore and New Zealand, although Singapore's domestic chemical firms follows closely in terms of returns to scale. Throughout the sample period, Northern Ireland consistently achieves scale efficiency exceeding 90%.

A cautionary note needs to be added to the interpretation of these results since it needs to be recognized that the flow measure of capital for the Northern Ireland's chemical sector differs from the stock measure used for New Zealand and Singapore when doing the pooled analysis. For Chemical companies, where the stock of capital is likely to be high given the nature of the sector, then the use of the smaller flow measure of capital runs the risk of providing Northern Ireland with an unfair efficiency advantage. In particular, for any given level of output, Northern Ireland would appear to use less capital. The effect of this data measurement risk would be for Northern Ireland's efficiency to significantly dominate New Zealand and Singapore. Despite this potential, it does not appear to be the case and, in particular, the pooled results for each economy/region appear similar to the single frontier results. This again suggests that the use of capital flows for Northern Ireland has not overly impacted the results.

Chemical Efficiency - Malmquist Indices

Efficiency development in Northern Ireland's chemical sector is presented in Figure 24. For most of the period, Total Factor Productivity growth was positive, but declining. On average the sector managed to grow productivity by 2% per annum. This growth was achieved by improved best practice, depicted by technological improvements, improved scale economies and by a slowing of technical inefficiencies.

Figure 24

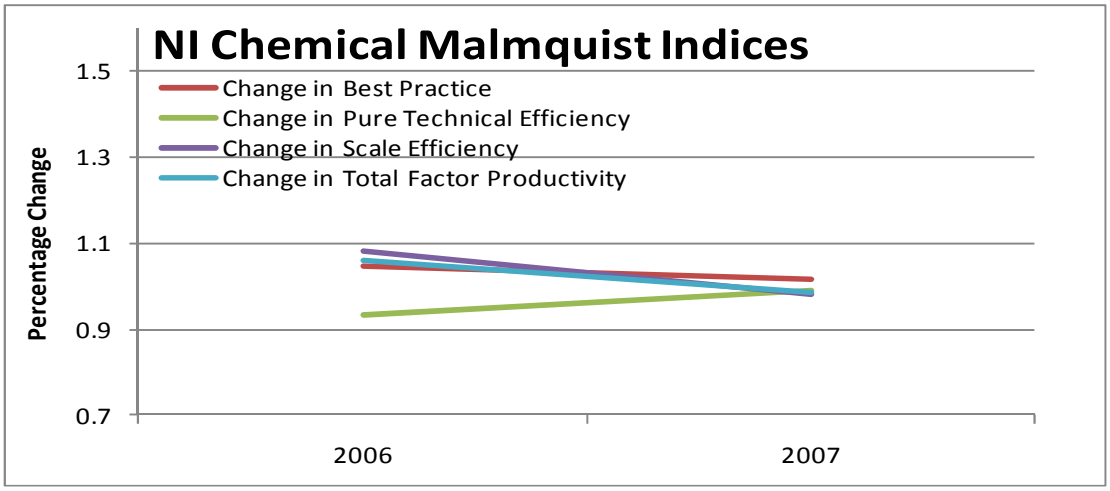


Figure 25

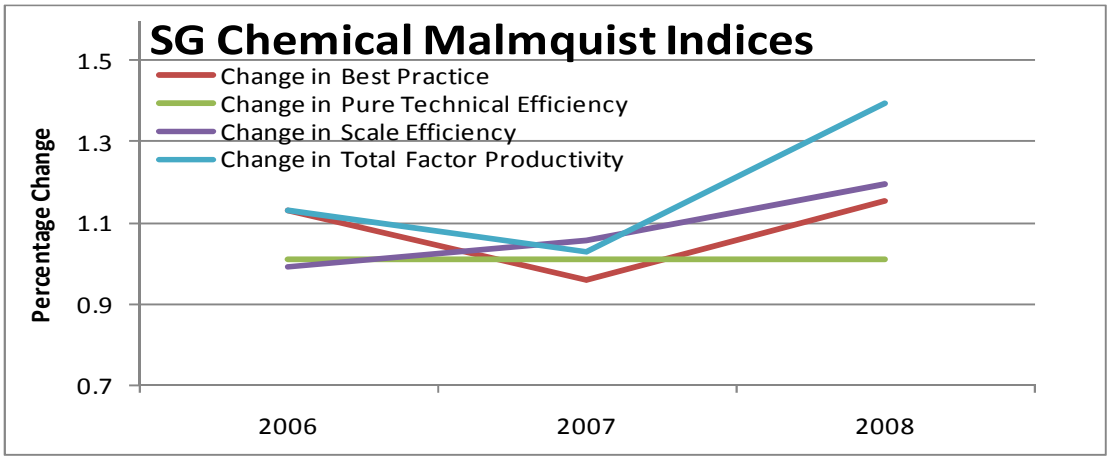
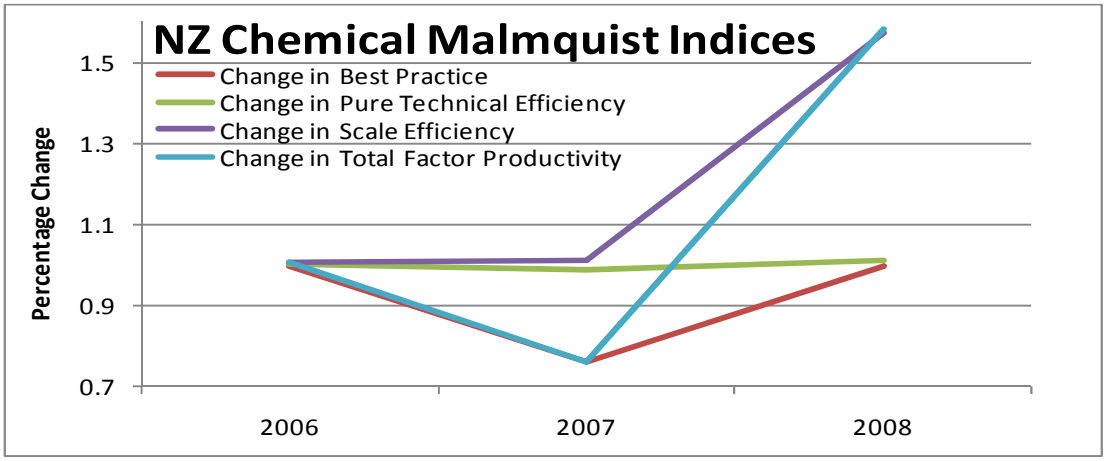


Figure 26



Total Factor Productivity growth averaged 17% per annum in Singapore's chemical sector, see Figure 25. Technical efficiency contributed very little to this growth. But scale efficiency improvements and technological improvements of over 7% per annum were significant in improving overall productivity.

In New Zealand, as indicated in Figure 26, Total Factor Productivity exhibits a variable path. Between 2006 and 2007 productivity declined by almost 30% and then climbed by over 50% between 2007 and 2008. The dramatic drop was caused by a reduction in best practice, whilst, the later improvement in productivity is attributable to an improvement in scale efficiency.

Summary – Chemical Sector

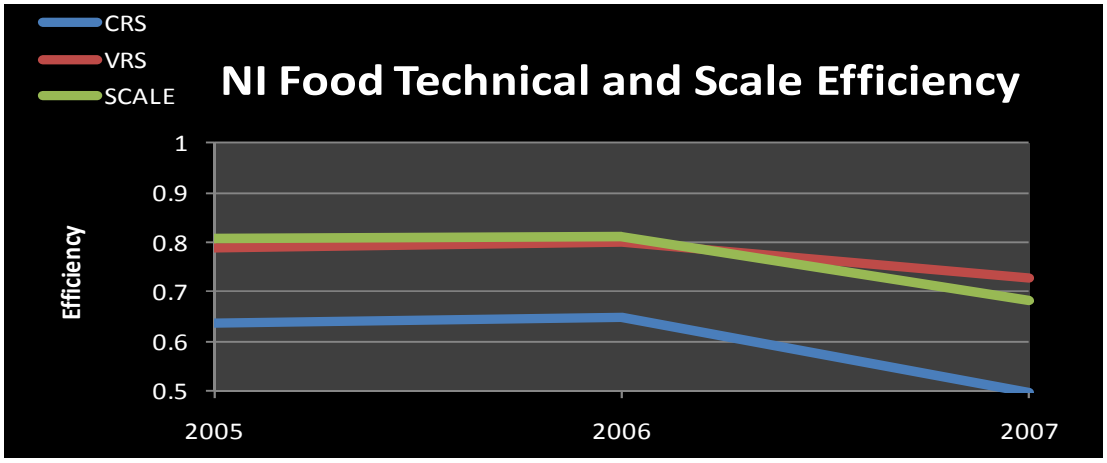
The efficiency results for the Chemical sector in Northern Ireland show a number of positive aspects. Scale efficiency within the sector is high, both when measure within the sector and when compared against the chemical sector in New Zealand and Singapore. Technical efficiency is reasonably strong and dominates the other locations when a pooled analysis is used. Finally, Northern Ireland is unique in driving total productivity growth in this sector throughout the period. Importantly, this productivity growth appears to lead to improvements in best practice. The

analysis is limited by the lack of data on the Republic of Ireland's chemical sector. Future analysis would be particularly useful given the importance of the Chemical sector as a leading export sector for Ireland.

Food Efficiency – Single frontiers

The technical and scale efficiency for the Northern Ireland's processed food sector are presented in Figure 27. Technical efficiency and scale efficiency are reasonably high averaging between 70% and 80% in each year. This sector in Northern Ireland was the biggest sample with 92 firms. This sample does not contain the largest and publically listed companies that will be more likely to display strong scale and technical efficiency. Therefore, given the composition of companies within this sample, the slightly lower average technical and scale efficiencies, when compared with other sectors and economies, are reasonable.

Figure 27



In Singapore, the technical and scale efficiency of the processed food sector is below 100%, see Figure 28 (please note differences on the scaling of axis). Assuming variable return to scale, the technical efficiency is below 90% for most of the period under study. Scale efficiency is better, but in recent times exhibits a declining trend. The technical and scale efficiency results for the Republic of Ireland's processed food sector are presented in Figure 29. It is clear that throughout the period, this sector has been both technically and scale efficient. Technical and scale efficiency within the New Zealand Food sector are also strong, exceeding 95% on average throughout the sample period, see Figure 30.

Figure 28

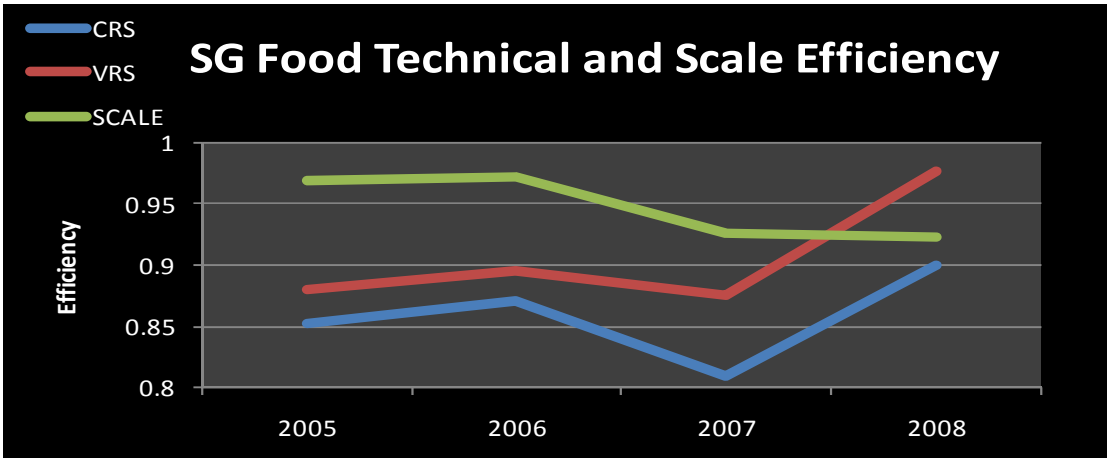


Figure 29

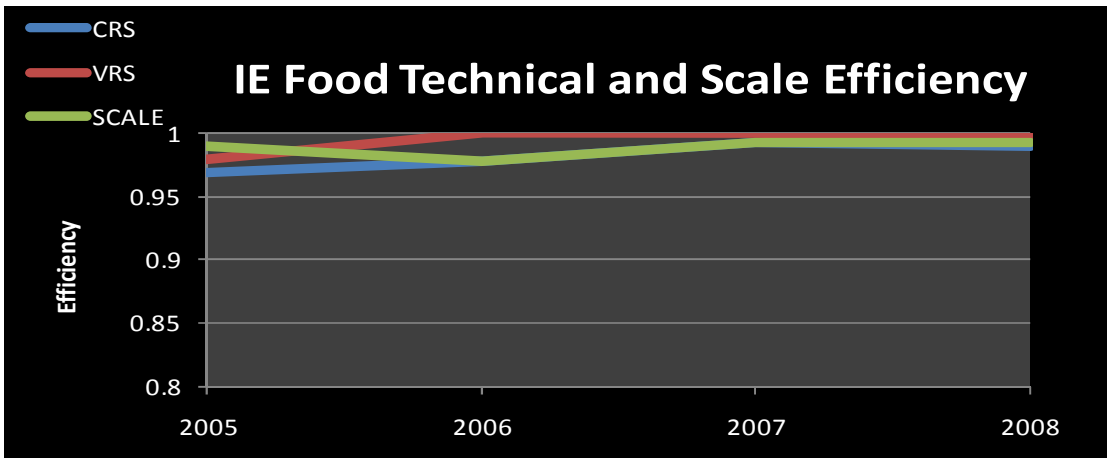
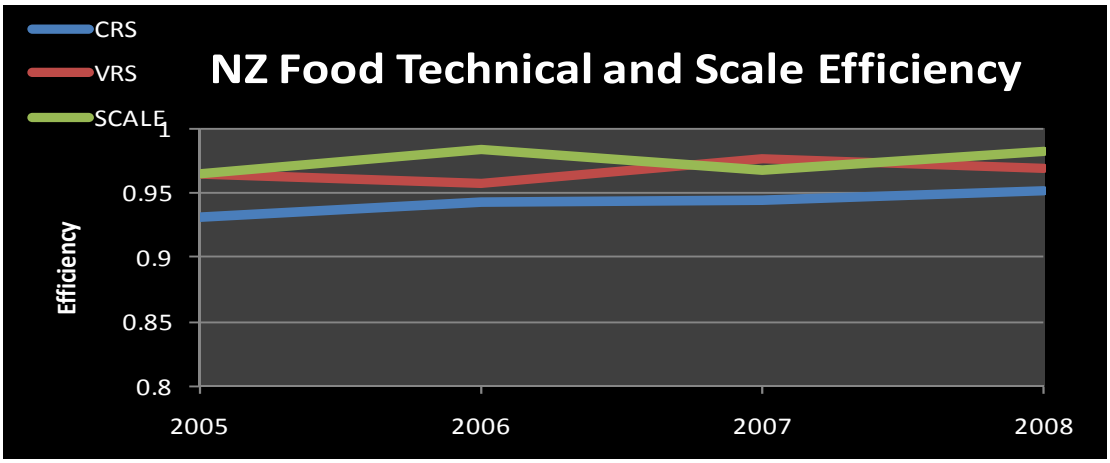


Figure 30



Food Efficiency – Pooled Frontiers

In order to assess the efficiency of the processed food sector in Northern Ireland against the other locations, the food sector data across all locations was pooled. DEA was then re-run and technical and scale efficiencies compiled for each location.

Figure 31

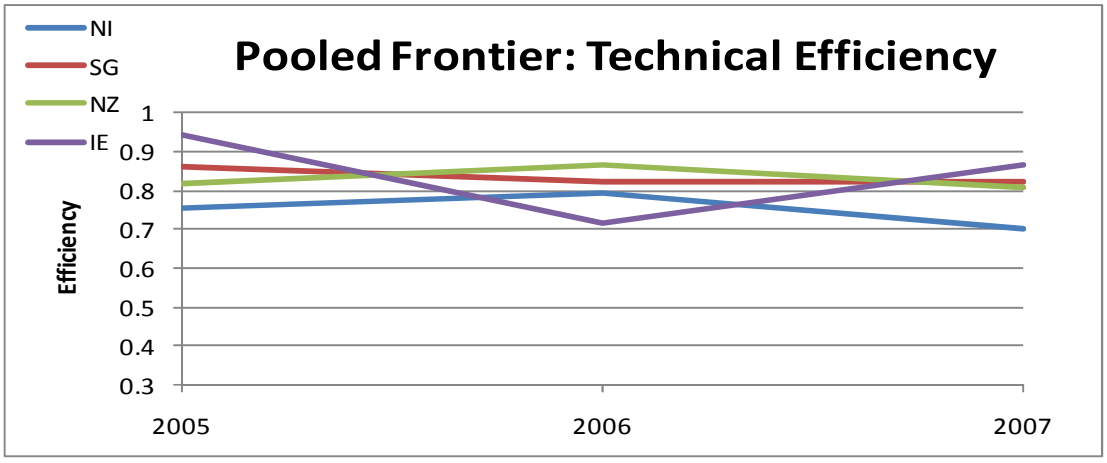
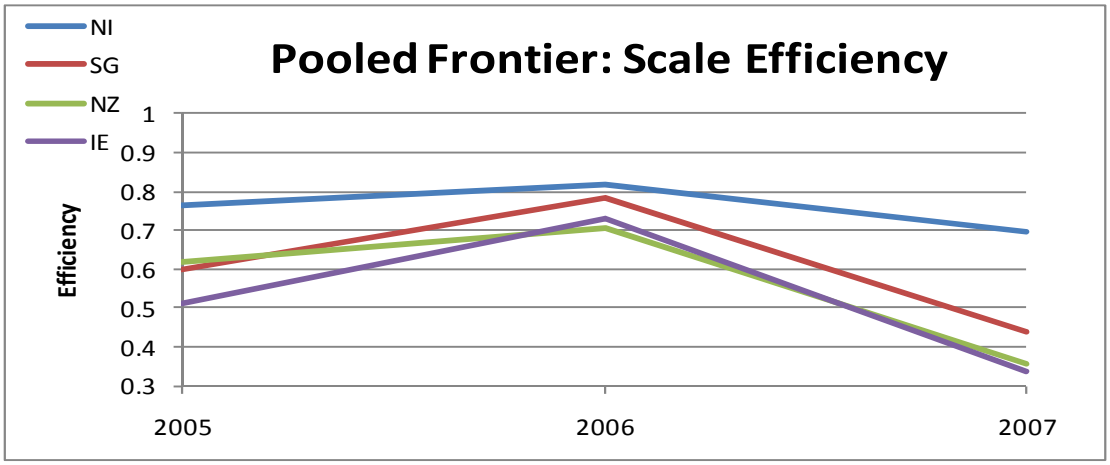


Figure 31 provides the variable returns technical efficiency scores. When compared with Singapore, New Zealand, and Ireland, technical efficiency in the Northern Ireland's processed food sector averages around 75%. This is a reasonably good level of efficiency, but it is the weakest of the entire sample. However, it should be noted that the sample companies from Singapore, New Zealand and Ireland are all large publicly-listed companies. The Northern Ireland sample contains many smaller companies who may have weaker technical efficiency, do not provide a significant amount of value added within the Food sector; but do drag down the overall average for technical efficiency in Northern Ireland.

Figure 32

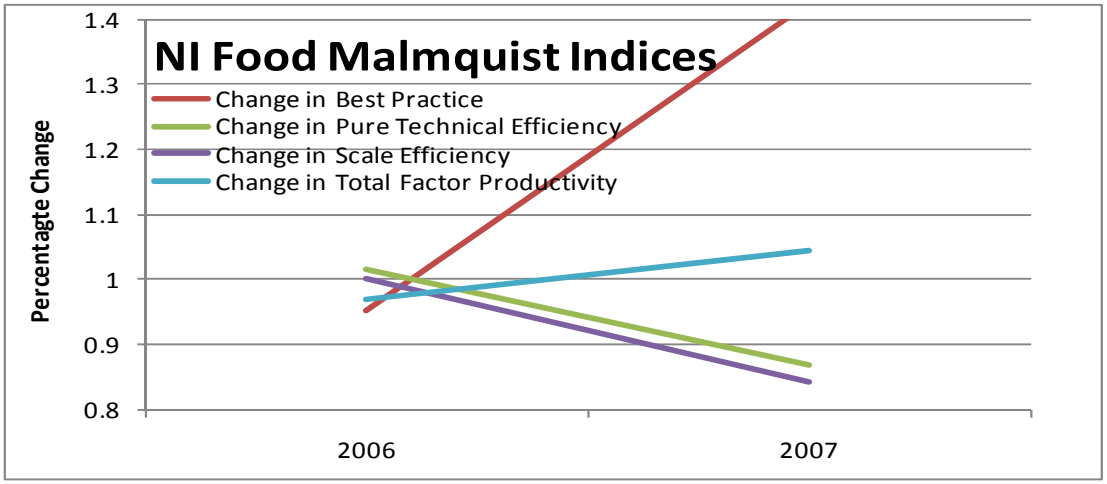


As indicated in Figure 32, scale efficiency within the Northern Ireland Food sector is superior to that in all of the other comparator economies. Northern Ireland achieves around 80% on average and consistently beats all of the other locations. The nature of the samples in Northern Ireland may explain the dominance of the results. For example, the Northern Ireland sample may contain a better mix of companies at the minimum efficient scale, along with some operating at increasing and decreasing returns to scale. Also the sample for Singapore, New Zealand and Northern Ireland (which consists of large listed companies) may contain more companies operating at decreasing returns to scale. This would explain the larger differences in scale efficiency in 2005 and 2007. But in 2006 Northern Ireland was only superior to the locations by around 10%.

Food Efficiency - Malmquist Indices

Throughout the sample period, the Northern Ireland's processed food sector managed to improve Total Factor Productivity by around 4.4% per annum. While the rate of technical and scale efficiency declined during the sample as indicated in Figure 33, the best practice frontier continued to improve and provided technological productivity gains. Such a performance might be explained by access to relatively cheaper labour, with the inference that for a smaller wage input, firms are able to generate increased output.

Figure 33



Malmquist indices for the Republic of Ireland's processed food sector are presented in Figure 34. Throughout the period, Total Factor Productivity growth averaged 3% per annum. But this represents a good rise between 2005 and 2006, followed by a marked decline through to 2008. The primary cause of this decline is the reduction in technology/best practice operations.

Figure 34

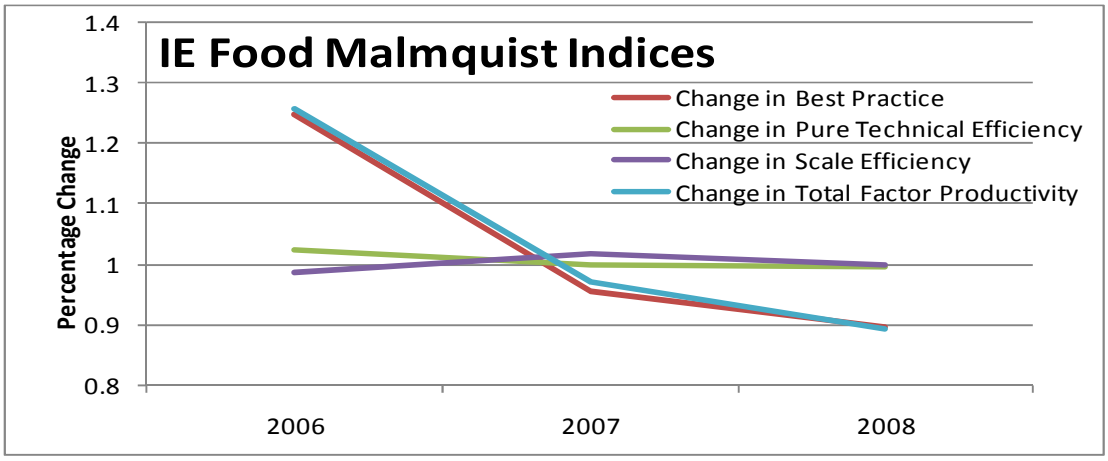


Figure 35

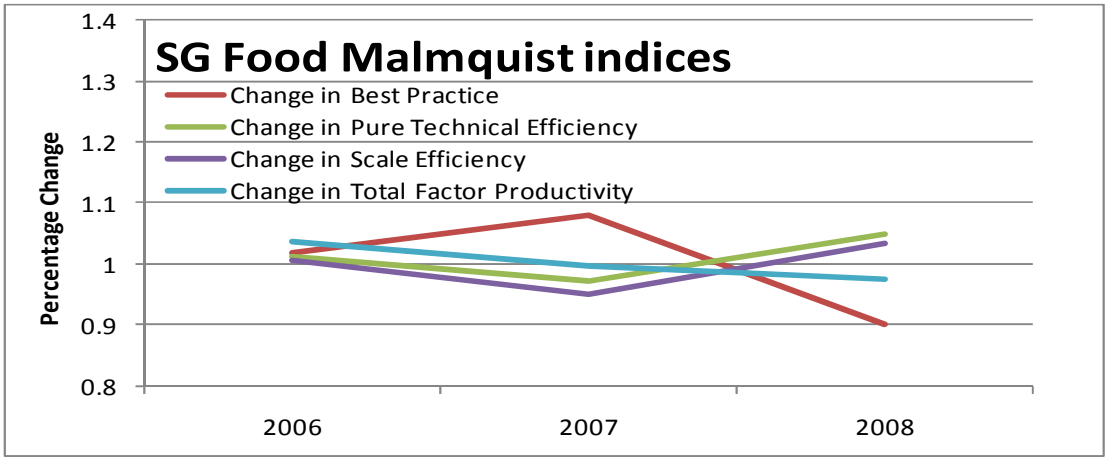
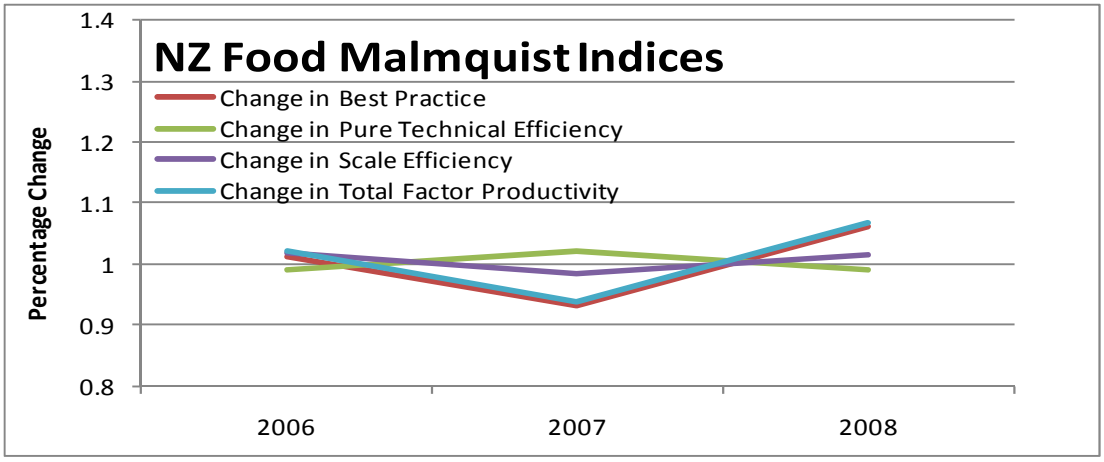


Figure 36



In Singapore, the processed food sector has experienced little factor productivity growth through the period 2005 to 2008 as illustrated in Figure 35. The New Zealand's processed food sector also experienced little factor productivity growth during the sample period, see Figure 36.

As earlier with the New Zealand's chemical sector, this sector also experienced a decline in productivity between 2006 and 2007. This was also driven by a reduction in technology/best practice operations.

Summary – Food

The Northern Ireland Food manufacturing sector appears to be the weakest sector in terms of efficiency. Technical and scale efficiency measured within Northern Ireland shows good levels of efficiency, but these are generally weaker than the efficiency levels found in the other economies. In particular, New Zealand, perhaps one of the world's leading Food exporters manages to achieve almost 100% technical efficiency.

The pooled measures of efficiency confirm that Northern Ireland is weaker than all the other locations in terms of technical efficiency, while in contrast, Northern Ireland exhibits the best scale efficiency. Another promising feature of the Northern Ireland's processed food sector is the growth in Total Factor Productivity. This has averaged in excess of 4% per annum and has been driven by technological gains.

5. Conclusions

This report examined important internationally trading sectors for the economy of Northern Ireland from the perspective of efficiency in terms of technical efficiency, scale efficiency and Total Factor Productivity. The analysis focuses on the Banking, Chemical and Food sectors as relevant sectors in the economic activities and international trade of the economies analysed. The efficiency analysis is initially applied to firm-level data within each economy and then compared to the same sectors across our set of benchmark economies. The selected benchmark economies are the Republic of Ireland, Singapore and New Zealand since our focus is on understanding the approaches and strategies for productivity, innovation and competitiveness challenges facing small open economies to garner the best practice insights for the PIC SOE project.

Data Envelopment Analysis is a commonly-used efficiency technique. This technique is appropriate for the estimation of technical efficiency, scale efficiency and the measurement of Total Factor Productivity growth. The results indicate few efficiency weaknesses within Northern Ireland's Banking, Chemical and Food sectors. Often, Northern Ireland is one of the strongest performers in terms of efficiency and, more importantly, has managed the fastest improvements in Total Factor Productivity in two of the three sectors.

The statistical analysis of three leading banks in Northern Ireland suggests that technical efficiency within the sector is strong and they have achieved substantial returns on scale. Banks in Northern Ireland, on average, are efficient at converting inputs into outputs, and generating strong output from available inputs. The average rate of productivity growth (TFP basis) was the highest in our sample at 4%. However, when compared on the basis of technical efficiency across all banks in our benchmark countries (in our pooled analysis), the results place Northern Ireland in the lowest ranking in terms of technical efficiency, but still strong in scale efficiency. These results may reflect genuine technical efficiency inferiority or might also represent differences in the

nature of value added services provided and performed in other economies. For example, a greater number of complex (and more lucrative) financial transactions are likely to take place in locations such as Singapore and possibly the Republic of Ireland given the multinational activities located there. It should also be recognised that the cost of serving rural economies in Northern Ireland may also hamper technical efficiency, relative to other locations. In technical efficiency scores, Northern Ireland tracks New Zealand most closely. If New Zealand is taken as a more reasonable comparator for Northern Ireland's banks, then Northern Ireland has achieved a good level of technical efficiency.

Focusing on the chemical sector, our estimations indicate that it is comparably efficient. In our separate pooled analyses for technical efficiency, Northern Ireland displays sound performance – comparable to Singapore and above that of New Zealand. The scale efficiency of firms in Northern Ireland, relative to counterparts in our sample, indicates they are operating at a relatively more efficient scale. The degree to which firms in this sector could be more productive is somewhat limited by their scale (when defined in terms of the appropriate scale to maximize output given available inputs) but to a lesser extent than that of the comparative sectors in the benchmark economies. Total Factor Productivity has improved most in the sector for Northern Ireland compared to Singapore and New Zealand. The particular analysis is limited by the lack of data on the Republic of Ireland's chemical sector

Analysis of the scale and technical efficiency of firms across the processed food sector within Northern Ireland indicates rates of between 70% and 80% for the period considered. However, when compared to the Republic of Ireland, Singapore and New Zealand, it indicates the weaker technical and scale efficiency. The processed food sector is clearly one of importance in efficiency terms for all the economies considered. Again it is important when interpreting these results to recognize that the competitive features of the sectors are very different across the economies. Several large publically traded companies in this sector operate out of Singapore, New Zealand and the Republic of Ireland relative to the Northern Ireland where our sample contains many relatively smaller companies who may be unfairly compared given the analytical approach adopted. This is evident from the relatively strong performance of companies in terms of scale efficiency (pooled results). While our results indicate potential opportunities for improvement, it should also be noted that best practice within the sector is strong and Total Factor Productivity has grown at over 4% per annum.

The results have some limitations which stem from the availability of data. It may be useful in the future to gain plant level data for the chemical sector in the Republic of Ireland and it may also be useful to gain stock measures of capital, rather than use flow measures for Northern Ireland. We also know from the ESRC (2008) that since 2003, Northern Ireland has experienced increasing productivity growth rates and that its productivity growth was above the OECD average over the period 2003-2006 well above those in the previous period. However, based on the assumption that this performance was not an outlier, we can interpret our results with confidence. This assumption would appear valid since Northern Ireland displayed the highest rate of economic growth (measured in terms of Gross Value Added (GVA) per capita) of all UK regions between 1989 and 2004 (Iparraguirre D'elia, 2007).

It remains for further elements of this research to investigate the reasons that underlie the ability of firms in Banking, Chemical and Food sectors, among others, in Northern Ireland to consistently achieve improvements in Total Factor Productivity. Over short periods it would be expected that technical and scale efficiency would change as firms adapt to changing competitive circumstances. It is their productive performance over time that determines the extent to which firms can generate positive contributions to their economies through revenues, jobs and the generation of knowledge, including innovation that can be put to further productive uses. As firms in Northern Ireland in our sample of sectors display a trend of improving productivity and in improving best practice year on year there is sufficient indication of a learning capability across firms in the sectors considered.

Our analysis must turn to a closer examination of how this is achieved and how the rate of growth can be supported. Such issues are important for both policymakers and business practitioners.

Finally, the use of Data Envelopment Analysis to measure efficiency within key sectors of the Northern Ireland economy is believed to be a novel approach. The method and approach described within this investigation is equally applicable to most sectors and therefore should provide DETI with a future means of assessing performance in efficiency terms within Northern Ireland and relative to other locations.

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