Essays on effects ot trade and technological change on skilled and unskilled workforce : evidence from the Australian economy

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Due to the ongoing globalisation, freer market operations, and technological change, Australia's labour market has been going through significant structural changes over recent years. As a result, the pay conditions of its skilled and unskilled workers have been rapidly changing with possible increase in wage gap. This study examines how technological change and international trade could affect wage inequality and employment ratio between skilled and unskilled workers at macroeconomic, industry, and firm levels in Australia. Calibrated wage ratios with different factor-biased technological changes have been measured and compared with observed skilled-unskilled wage ratio at macro level. Factor content of trade and existence of Stolper-Samuelson effects have been examined to find the trade effects in manufacturing industries. Intra-industry trade indexes have been calculated and used to find the relationship between Australia's trade patterns with its trading partners of different income status. This sheds lights on the effects of increased trade from low-wage countries on Australian labour market. Using firm level Business Longitudinal Survey (BLS) data, Random effects panel regression models have been used to find the effects of different technological change indicators on Australian labour market. The major findings are, (i) among different factor-biased technological changes only skill-biased technological change could explain some of the observed skilled-unskilled wage ratio at the macro level. (ii) With few exceptions, in most of the manufacturing sectors in Australia, increased trade with developing countries could not explain the rising wage inequality and increased demand for skills. (iii) Technological change is found to cause the shifts in skill demand in all but one two-digit manufacturing industries. (iv) For firms in most of the sectors, there has been strong evidence that some of the technological change variables have caused extensive skill-biased technological change and hence, reduced relative unskilled employment especially in the firms of low-skill intensive sectors. Appropriate policies of training and job replacement programmes for unskilled workers have been recommended for Australia. Policies to increase trade barriers have not been recommended as these would reduce welfare of the economy and attract retaliations from trading partners.

ESSAYS ON EFFECTS OF TRADE AND TECHNOLOGICAL CHANGE ON SKILLED AND UNSKILLED WORKFORCE: EVIDENCE FROM THE AUSTRALIAN ECONOMY

By

Wahida Yasmeen

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

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ABSTRACT

Due to the ongoing globalisation, freer market operations, and technological change, Australia's labour market has been going through significant structural changes over recent years. As a result, the pay conditions of its skilled and unskilled workers have been rapidly changing with possible increase in wage gap. This study examines how technological change and international trade could affect wage inequality and employment ratio between skilled and unskilled workers at macroeconomic, industry, and firm levels in Australia. Calibrated wage ratios with different factor-biased technological changes have been measured and compared with observed skilled-unskilled wage ratio at macro level. Factor content of trade and existence of Stolper-Samuelson effects have been examined to find the trade effects in manufacturing industries. Intra-industry trade indexes have been calculated and used to find the relationship between Australia's trade patterns with its trading partners of different income status. This sheds lights on the effects of increased trade from low-wage countries on Australian labour market. Using firm level Business Longitudinal Survey (BLS) data, Random effects panel regression models have been used to find the effects of different technological change indicators on Australian labour market.

The major findings are, (i) among different factor-biased technological changes only skill-biased technological change could explain some of the observed skilled-unskilled wage ratio at the macro level. (ii) With few exceptions, in most of the manufacturing sectors in Australia, increased trade with developing countries could not explain the rising wage inequality and increased demand for skills. (iii) Technological change is found to cause the shifts in skill demand in all but one two-digit manufacturing industries. (iv) For firms in most of the sectors, there has been strong evidence that some of the technological change variables have caused extensive skill-biased technological change and hence, reduced relative unskilled employment especially in the firms of low-skill intensive sectors.

Appropriate policies of training and job replacement programmes for unskilled workers have been recommended for Australia. Policies to increase trade barriers have not been recommended as these would reduce welfare of the economy and attract retaliations from trading partners.

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TABLE OF CONTENTS

LIST OF TABLES

Chapter Three

Chapter Four

LIST OF FIGURES

Chapter One

Introduction

1.1 Background

In recent years rising relative wage of skilled workers compared to that of unskilled workers in many of the developed countries, such as, U.S., U.K., and Australia, has become a major concern among the economists. While the increased wage inequality is the concern for some of the developed countries some other countries have seen more stable wage structures. In several European countries and almost all countries experienced shifts in employment structure that have adversely affected unskilled workers (Machin and Van Reenen, 1998). Many economists believe that the increased wage inequality among the skilled and unskilled workers accompanied by rising relative skilled employment in developed countries is due to the increased international trade with the developing (low wage) countries. Other economists believe that much of the wage inequality among the skilled and unskilled workers stems from the impact of new technology. This research has been aimed to deal with the issue that is of ongoing interest and concern – the effects of increased international trade and of technological change on unskilled workers in Australia. In this research the issue of changes in relative wages and employment between skilled and unskilled workers has been examined purely on equity grounds and not as a policy problem because of a market failure.

Over the last decades, growing trend of globalisation and policy shifts in international trade have given rise to obvious concerns as to whether such integration would ensure equitable share of the expanded global economic pie for the trading nations. There has been a consensus that increasing openness is more likely to enable an economy to allocate resources consistent with its comparative advantage in trade (Tybout, de Melo and Corbo, 1991 and Iscan, 1998). Liberalised international transactions provide producers and factor inputs freer access to global market and help promote competitiveness through increased global competition. As a consequence, payment differential between more productive and less productive factors, such as skilled and unskilled labour, is likely to increase.

Historically, an economy's expansion and development path has been built along the process of accumulated know-how and use of such knowledge, often reflected in the nation's technological progress. As the economies moved up along the technological ladder, there has been a shift in these economies from agriculture and other primary producing activities to manufacturing industry and to skill intensive sectors. Such movement along the technological ladder and the resultant need for skills has steadily increased demand for and return to skilled workforce over time in developed economies.

The above discussions imply that both trade and technological change are among the major factors that contribute to rising wage inequality among the skilled and unskilled workers. Economic theory suggests that with skill-biased technological advancements, demand for skills would increase and the return to skills would also increase causing rising wage inequality among the skilled and unskilled. On the other hand, increasing trade is likely to cause major distortions in the global market prices of various products and therefore, could be a major factor responsible for rising skilled and unskilled wage differentials.

The purpose of this study is to provide a comprehensive examination of whether trade or technological change has been the fundamental cause of rising wage inequality in a developed economy like Australia, which possesses certain distinct characteristics of its own. Australia is among the very few high income developed economies that possess a vast agriculture and primary resource sector and a moderate industrial sector. In recent years, Australia has heavily embarked on more capital intensive production processes with newer technologies, policies of phased reduction of protection from international trade and a considerable increase in use of Information and Communication Technology. With technological change and liberalised international trade, there have been significant changes in the structure and composition of labour market in Australia over the last two decades or so.

1.2 Objectives of the Study

This study has been undertaken with the following objectives:

i. To examine how factor (i.e., capital, skilled-labour, and unskilled-labour) biased technological change could explain rising wage inequality in Australia.

ii. To evaluate the extent to which international trade could affect the rising wage inequality among the skilled and unskilled workers in some of the Australian manufacturing industries.

iii. To examine how technological change affects the demand for labour and the skill mix of firms in different sectors.

iv. To examine sub sector and firm level policy options for Australian labour market.

The above objectives imply that this research purports to analyse the causes of shifts in skill mix in the labour market from both macro and micro perspectives. Since individual firms react to the changing environment in which they operate, where changes are due to public policies and administration, market economic fluctuations and international institutions; the micro-macro links should be a powerful basis for policy synthesis (Brimble, 1993). Changes in international institutional and government policy serve as stimuli imposing pressures of varying degrees on Australian labour market. These pressures, signaled in terms of increased competitions, require the firms to respond through introduction of new, more efficient and advanced technologies for production, changing skill mix and intermediate inputs and improving management related issues. The success, to which firms or specific sectors respond to a particular stimulus, depends on a number of factors that are firm or industry specific, in addition to those emanating from the sector or environment within which the firms or industries are operating. In macro level, the policy makers would be eager to know and understand the success and effects of their liberalising or other policies on the economy as a whole as well as on the industry and establishment levels.

1.3 Structure of the Thesis

This chapter provides a brief overview of the rationale and objectives of this study. The chapter also explores the significance of examining the pattern of wage differentials and factors affecting such differentials in Australian industries at both sub sector and firm level. The rest of the thesis has been designed as follows:

Chapter Two provides a brief survey of relevant literature. The chapter has covered discussion on literatures contributing to both theoretical development and applied issues pertinent to pattern of labour market and rising wage inequality.

Chapter Three examines how different factor-biased technological changes are capable of explaining the observed wage inequality in Australia. The chapter explores specific capability of calibrated wage ratios with capital-biased, skill-biased, or unskilled-labour biased technological changes separately, in explaining the observed skilled-unskilled wage ratios in Australia at macroeconomic level. A two-stage Constant Elasticity of Substitution production function has been used in this chapter to accommodate three different factors of production (capital, skilled and unskilled labour) in the analysis.

In Chapter Four, an overview of Australian trade for last two decades has been presented. It also investigates the existence of Stolper-Samuelson effects in some manufacturing industries. Counterfactual trade effects have been calculated for three-digit manufacturing sectors and presented in terms of two-digit manufacturing sectors. Moreover, impacts of trade with countries of different income status on trade-pattern of Australian manufacturing sub-sectors have been investigated and elaborated based on the new trade theory and comparative advantage theory of international trade. The major contributions of this chapter to the existing literature emanate from the fact that, while examining international trade effects on labour market, most of the studies (discussed in detail in Chapter Four) overlook the different types of trade involving various countries and sectors. This chapter addresses the question regarding the type of trade Australia has with its developed and developing trading partner countries. It also examines whether increased trade with developing countries would cause significant net job losses and would cause significant shifts in wage distribution among workers of different skill levels.

Chapter Five includes the findings of *within* and *between* industries components of shifts in skilled demand for the two-digit manufacturing industries of Australia. Empirical evidences from firm level data of the effect of technological change on Australian labour market have also been provided in Chapter Five. Upon categorising the firms according to various sub sectors, Random Effect models for panel data have been used to examine the effects of various firm specific technological change indicators on employment, wages, and skilled-unskilled employment ratio in different sectors. In existing literature very little attention has been paid to find the magnitude of the technological change effects on the labour force and job conditions. More importantly these issues have rarely been examined from a microeconomic perspective. Keeping these in mind, this chapter examines the effect of various technological change indicators, other than the traditional technological change indicators, on Australian labour market using firm level longitudinal data over the period of 1995-96 to 1997-98. This study also controls for trade liberalisation and labour institutions by including export intensity and unionisation as explanatory variables. This chapter also investigates whether technological change experienced by any sector has been intensive (implying that efficiency of skilled-labour goes up) or extensive skilled-biased (meaning that skilled workers can perform some the works previously performed by unskilled workers). When the technological change is extensive skill-biased the unskilled workers would be affected both terms of wages and employment. On the other hand, intensive skill-biased technological change could make the skilled workers better off both in terms of wages and employment without affecting the unskilled employment.

In conclusion, Chapter Six summarises the major findings of this study and recommends a number of policies that flow from the results. The chapter ends by indicating some limitations of the study and by providing some directions on possible future research in this area.

Chapter Two

The Debate on Trade, Technology and Rising Wage Inequality: A Brief Literature Review

2.1 Introduction

Beginning from the late 1970's, rising relative wages of skilled labour compared to the wages of unskilled labour accompanied by increasing unskilled unemployment has become a major area of concern among the economists. This issue has generated a lively debate, specifically between labour economists and trade economists. Consequently, there have been significant amount of efforts made by researchers and policy makers to appropriately address the problem of rising wage inequality and to find a solution to this issue. A good number of theoretical models have already been put in places that explain the pattern and causes of rising wage inequality among skilled and unskilled workers. Some of these models include the Heckscher-Ohlin (H-O) theory of international trade, Factor Price Equalisation (FPE) theory, factor content measurement of trade and general equilibrium model. Economists have arrived at different conclusions about the cause of rising wage inequality; while some detected increasing international trade others identified technological change as the cause behind rising skilled-unskilled wage gap. There have been other researchers who pointed at the structural change in labour market as the factor responsible and suggested that the issue ought to be investigated well in the future.

In section 2.2, literatures that found evidence in favour or against international trade being the reason of rising wage differential has been discussed. The second stream of studies that identified technological change as the main factor responsible for the wage differential has been reviewed in section 2.3. In section 2.4, the effects of trade and technological change found in the Australian labour market have been explored. At the end of the chapter, a brief discussion on the policy implications suggested by the trade economists and labour economists has been presented.

2.2 Evidence of International Trade Effects on Wage Inequality

There have been quite a large number of researches done by economists to pursue the issue of rising wage inequality to reveal the real volume as well as causes of rising wage inequality. The rising wage inequality is different in size and pattern for different developed countries. A review of the evidences on the trend of rising wage differential suggests different causes behind such trend that exists in different developed countries. All of the existing studies agree to one argument - the wage of unskilled labour compared to the skilled labour has decreased in real terms in the developed countries over the last couple of decades (Kosters 1989; Murphy and Welch, 1991; Blackburn 1990/91; Bound and Johnson, 1992). For example, in the United States, the average wage of a college graduate increased by 15 percentage points relative to a high school graduate over the period of 1979 to 1988 (Bound and Johnson, 1992).

In 1980s and 1990s, with increasing globalisation and international trade liberalisation the demand for the unskilled labour as well as their wages have fallen significantly compared to the skilled labour in the developed countries. This trend has started to become apparent as the developing countries (namely, India, China, and Indonesia) started to lift up their trade barriers with developed countries and joined the integrated global economy. Hence, it is not surprising that the growing international trade among developed and developing countries is being accused as a primary reason for wage inequality.

The problem of rising wage inequality poses a different threat to the U.S. than to the OECD-Europe. In the U.S. the real earnings, as well as the standard of living of workers in the bottom deciles of earnings distribution have fallen in an alarming rate, (the hourly rates of males with 12 years of schooling fell by 20 percent between 1979 to 1993) and the earnings of the workers in the upper deciles have risen - widening the wage gap of skilled and unskilled workers (Freeman, 1995). Evidence shows that the ratio of wages between skilled (non-production) and unskilled (production) workers in the U.S. fell in mid 1960s and fluctuated without showing any trend in the rest of that decade. In early and mid 1970s, the inequality narrowed and remained quite flat until 1982. From 1982 to 1990, the ratio of skilled to unskilled wages increased by 7.9 percent (Sachs and Shatz, 1994).

In the U.S. the effect of the decline in the relative demand for less-skilled workers has resulted in lower wages for the less-skilled as the wages are highly flexible in U.S. The problem in OECD-Europe appeared in the form of growth of unemployment. In these countries wages are sticky downward and hence the decline in the demand for less-skilled workers resulted in high unemployment. Since World War II till early 1980's, the unemployment rate in OECD-Europe was lower than that of the U.S. For example, in 1973, the unemployment rate was 2.9 percent in OECD-European countries and 4.8 percent in the U.S. However, since 1983, the unemployment rate of the OECD-Europe started to be well above (9.3 percent) the unemployment rate of the U.S. (6.7 percent). The experience with the wage inequality was also different in OECD-Europe. The real income at the bottom of the income distribution in the OECD-Europe have actually increased, reducing the effect of high unemployment rate, which would have been devastating otherwise (Freeman, 1995).

Using panel data of U.S. metropolitan areas in a general equilibrium model, Borjas and Ramey (1995) showed that international trade in concentrated industries (durable-goods industries) and aggregate wage inequality are positively related. They suggested that net imports of goods produced in concentrated markets have the most impact on the wage structure, as opposed to the findings of most of the other economists, who believe that international trade affects the employment as well as real wages of unskilled workers in the competitive sector (Sachs and Shatz, 1994). Borjas and Ramey's findings also show that from 1976 to 1990, 23 percent of the increase in wage inequality can be explained by the shift of workers out of the concentrated sector with the assumption of unit factor elasticity of substitution. Trade explains half of the decline in employment, which implies that increase in trade in the concentrated industries could explain only 10 percent of the aggregate increase in wage inequality. As a result, they concluded that their theory could not explain all of the observed increase in wage inequality over the period of 1976 to 1990. They suspected that technological change could be the explanation for the rest of the increase in inequality.

According to the conventional H-O theory of trade, when two countries begin trade, each one will specialise in the product 'that is intensive in its abundant factor' (Sachs and Shatz, 1994, p.13). In the case of trade between developed and developing countries where skilled and unskilled labour being the factors of production, it is expected that developed countries will specialise and export skill-intensive goods and developing countries will specialise and export low-skill-intensive products. This is due to the fact that developed countries are endowed with skilled labour and developing countries are endowed with unskilled labour. According to the predictions of H-O theory, the results that would follow in the developed countries are, (i) the price of low-skill-intensive products will fall because of the competition from the products from the low-wage countries; (ii) relative wage of unskilled workers will drop and as a result the ratio of unskilled and skilled labours will increase in the production sectors; (iii) production and export of skill-intensive products will increase and those of unskilled-intensive products will decrease. In the developing countries just the opposite trends will follow.

To examine the relevance of H-O model to explain U.S. trade patterns Sachs and Shatz (1994) has classified one hundred and thirty one three-digit manufacturing sub-sectors of U.S. according to the skill intensity of the industries. They found that in 1990, production (unskilled) workers were 41.2 percent of total employment in the most skill-intensive industries and were 86.7 percent in the least skill-intensive industries. They also found that U.S. is the net exporter of skill-intensive products to the developing countries. For example, in second and third deciles of skill-intensive products (more skill-intensive sectors), net trade (exports minus imports) of U.S. was 66.5 percent and 10.9 percent of total trade. On the other hand, in ninth and tenth deciles (least skill-intensive sectors) the net trade of U.S. with developing countries were -79.0 and -75.0 percent, respectively. These findings are in accord with the H-O model of international trade. Sachs and Shatz (1994) also found that for each decile (1 to 10) the employment of unskilled workers as percentage of 1978 employment level fell during the 1978-1990 period and such decline was largest in low-skill intensive deciles. In first decile (the most skill-intensive sectors) the change in production (unskilled) employment was -4.1, whereas in ninth and tenth deciles the changes were -21.9 and -29.1 percent, respectively.

Moreover, if the H-O theory prevails, the increase in trade with low-wage partners would reduce the demand for unskilled workers in the developed countries. Sachs and Shatz used the counterfactual measurement of trade approach (factor content of trade measurement) using fifty one manufacturing sectors of U.S. to investigate the effect of increased imports of manufacturing products, from low-wage countries, on employment. In factor content measurement of trade, the use of skilled and unskilled workers in the country's exports and how much of that would have been used if the country would produce its imports domestically, has been calculated. The increased demand due to the counterfactual measurement can be considered as the amount of job losses that results from the increased volume of trade between the base year and the current year. Sachs and Shatz compared what would be the employment levels of U.S. manufacturing industries in 1990 (the current year) if the import share remained at 1978 (base year) levels with employment at the actual share – all other determinants remaining constant[1]. According to the finding of Sachs and Shatz (1994) 7.2 percent of unskilled workers and 2.1 percent of skilled workers lost their jobs because of the increase in imports over the period 1978 to 1990. Many of these job-losses were the direct consequences of increasing trade of U.S. with the developing countries.

As manufacturing industries employed only 16 percent of United States non-agricultural labour force in 1993, it could be difficult to show and conclude that increased trade from developing countries had significant effects on widening absolute and real wages between skilled and unskilled workers. However, the evidence shows that starting in late 1970s and early 1980s the widening of skilled-unskilled wage gaps have the same timing as the increased competition from the low-wage countries. Along with this, the wages paid in export sectors increased and wages paid in imports sector decreased, again widening the wage inequality. Even after finding these evidences Sachs and Shatz (1994) did not find large enough relative price changes of skilled and unskilled-labour intensive products, which can explain the large widening of wage inequalities. This is in line with the findings of Lawrence and Slaughter (1993). They also did not find any decline in relative prices between skilled and unskilled-labour intensive products. They concluded that the increased competition from East Asia and Latin America has not caused any decline in the relative prices of products in manufacturing sector in the U.S. As a result, increased trade with developing countries cannot be the sole cause of increasing wage inequality among the skilled and unskilled workers.

Findings of Freeman (1995) were not big enough to explain all the fall in employment rate but large enough to become concerned about the increased globalisation and as a

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[1] The factor content measurement of trade has been discussed in Chapter Four and in Appendix A.4.II.

result, about the future trade policy of U.S. In case of U.S., where the relative wages are flexible because of the weak unions and very weak social security system, the real wages of unskilled workers can decline in a large proportion if there is a demand shock in the labour market. Even then the trade shifts the relative wages in a very negligible amount in the U.S. Also the changes in relative prices of skilled-labour intensive goods and unskilled-labour intensive goods due to the increased international trade are small.

In 1970s, the unemployment rate in Europe- was less than 3 percent and reached double digits by 1995. Krugman (1995) used factor content measurement of trade to estimate the proportion of unemployment in the U.K. caused by its trade with Newly Industrialised Countries (NICs). Krugman found that the fall in employment due to trade was 1.43 percent. His calculations were based on the extreme assumption of rigid relative wages among skilled and unskilled labours, which presumably exists in the U.K. and in other OECD countries. Because of the assumption of sticky downward wages in OECD-U.K., the adverse effects of growing trade with NICs were reflected in growing unemployment rate.

The Factor Price Equalisation (FPE) theory suggests that if one country is abundant in capital and another country is abundant in labour then these two countries will have comparative advantage in capital-intensive and labour-intensive products, respectively. Given this situation as the countries start trading with each other, the first country will export capital intensive and the second country will export labour intensive products. Both the countries will raise the production of goods they export and hence bid up the prices of the factor that used to be cheaper before trade. Hence the relative price of the abundant factor will increase and this will go on until the factor prices become same in both countries. In other words, according to the FPE theory, wages for unskilled workers in the developed countries will decline and be equal to the average world wage levels if there is free trade. Krugman (1995) argues that the factor price equalisation theory does not hold as soon as the trading countries specialise according to their factor endowments, which is the case here in the current example of trade between two countries. As a result of a rise in the relative price of skilled and unskilled intensive products, if the OECD countries cease to produce unskilled labour intensive products (that is, if they specialise in skill-intensive products) then the fear of factor price equalisation ceases. Any further increase in trade with NICs would not affect the relative income of skilled and unskilled workers. Therefore, according to Krugman (1995) this cannot be the principal reason behind these labour market phenomena in the advanced countries and perhaps not likely to pose a serious problem in the future.

Richardson's (1995) theoretical findings are closer to Krugman's rather than to Sachs and Shatz' (1994). Richardson found trade being a moderate reason for increasing income inequality among the skilled and unskilled workers in the short-run. He identified that in the long run both skilled and unskilled workers get better off from trade but the skilled workers are more benefited and this could raise income inequality. If the policy makers choose to tame trade just because of the above reason, it may cause the growth from trade to decline and help prevent the poor to be better off even not in relative to skilled workers.

H-O theory predicts that with reduction of barriers to trade there will be reduction of the relative price of low-skill intensive products in the developed countries. It also predicts that trade will increase the supply of unskilled-labour in the developing countries and hence will increase the production and export of low-skill intensive products by these countries. This will lower the relative price of these products in the world market. In fact, with the reduction of trade barriers along with the improvement of transport and telecommunications, this is what has been happening to the developed countries for the past couple of decades. Trade not only eased the flow of goods between developed and developing countries but also taught the companies in the developed countries to manage and disperse the productions and activities globally. If this is the case then a major question would be to ask why the findings of different economists show that trade did not affect the income inequality severely. Wood (1994) argues that the conventional factor content measures understate the number of unskilled workers that would be required in the absence of trade to meet the demand for imports. He showed that there are two other sources of understatement. First is the contribution of trade to technical progress. The firms try to fight off the imports by 'defensive innovation', which reduces the demand for unskilled workers. The second source is the confinement of factor content measurement only to manufacturing. Extending the factor content measures for the service sectors like shipping, tourism etc. would increase the factor content estimates and could explain the phenomenon of rising wage inequality. To cure this problem Wood (1994) suggests that one should calculate the number of workers used in the developing countries to produce the imports. This labour input then should be adjusted for higher level of wages and more skill and capital-intensive techniques to be used in developed countries. He argues that it should also be adjusted for the higher cost of production and hence lower demand for them. After the adjustment the factor content estimate would still be smaller than the actual number of labour embodied in them but much higher than the one suggested by conventional factor content measurements. By using his alternative method of factor content calculations, Wood (1995) showed that the conventional factor content results of Sachs and Shatz (1994) are much smaller than his results. According to the estimates of Sachs and Shatz (1994), factor content measurement effect of trade with developing countries on the demand for labour in U.S. manufacturing in 1990 were -6.2, -4.3 and -5.7 for unskilled, skilled, and all workers, respectively. In contrast, the alternative measurement by Wood (1995) gives the estimates for unskilled, skilled and all workers as -21.5, 0.3 and -10.8, respectively.

However, Wood's alternative measurement of factor content has been criticised heavily. Leamer (1994), whose findings are similar to Wood's, rejected Wood's alternative factor content measurement as 'measurement without theory'. According to H-O theory, trade affects wages by affecting product prices. Hence, Leamer believes that looking at product prices is well enough to estimate the effect of trade on the wages and there is no need for factor content estimations. Leamer (1994) argues that factor content measurement of trade is insufficient given the fact that prices cause changes in trade flows. He also states that Wood's factor content estimates require the elasticities of labour demand and supply, which are beyond the scope of standard factor content calculations. Another of Leamer's arguments is that the factor content estimates are not accurate due to the change in internal forces, like tastes, technology etc. These changes alter the factor content of a countries trade and the factor content estimations cannot control for these internal shifts.

Saeger (1995) estimated the changes in net imports of manufacturing products by the OECD countries from developing countries and the percentage change in the share of manufacturing employment in the total employment over the period of 1970 to 1990. Saeger's estimates showed that there is a strong negative correlation between these two variables.

Using U.K. manufacturing data of around one hundred and thirty five three-digit industries, Haskel and Slaughter (1999) estimated the effects of trade and technology on wage inequality among skilled and unskilled workers. They used the H-O trade theory based on the production side. They estimated the wage changes mandated by the change in the product prices and total factor productivity and compared the estimated wage changes with the actual changes. Their findings state that the change of the traded goods price worked as a major force, not the total factor productivity, for rising wage inequality in 1980s.

Murphy and Welch (1993) found that the change in employment and relative wages of workers, with different race, sex and education observed in the U.S. during late 1970's and throughout 1980's, could not be explained solely by the shifts in wage structure. They showed that the changing pattern of U.S. international trade could provide a non-negligible amount of explanation for rising wage inequality. International trade has caused an increased demand for women to men, whites to blacks and for better educated to less-educated workers raising the wage differential.

Using a panel data of manufacturing firms in Mexico for the period of 1984 to 1990, Revenga (1995) found that a 10-point reduction in tariff levels is associated with 2 to 3 percent decline in employment in Mexico. Changes in protection levels favour the non-production workers by raising the skilled-unskilled wage differential. Also, changes in levels of protection have a greater impact on the employment and wages of the production workers than on non-production workers of Mexican manufacturing.

2.3 Impacts of Technological Change on Wage Inequality

In search of the potential explanations of the dramatic changes in the U.S. wage structure in 1980s, Bound and Johnson (1992) used the data available from Current Population Survey (CPS) for the periods of 1973 to 1979 and 1979 to 1988 and found the following results. Firstly, total changes in average wage effects are in the right direction but can explain very small fraction of relative wage changes. Secondly, education and gender's effect were large but in the wrong direction. Thirdly, product demand shift effects are small and of uneven direction. Lastly, skilled-labour-biased technological change and changes in labour quality together were the principal source of the increase in wage differentials. Some of the relative wage changes remained unexplained in Bound and Johnson's findings. They forecasted continued rising wage inequality among educated (skilled) and less-educated (unskilled) workers unless the educational policies are changed to increase the college attendance and completion rates sharply.

Technological change also shows evidence of the widening of wage differentials starting in the 1980s but again cannot explain the entire rise in wage inequality. Using data on the production and non-production workers in U.S. manufacturing over the period of 1959 to 1989, Berman, Bound and Griliches (1994) found that capital-skill complementarity can not explain all the shifts in labour demand from production to non-production workers. They suggested that there could be other reasons behind the shifts in labour demand from unskilled to skilled, such as increased trade with developing countries, foreign outsourcing in specific industries or increase in defence department procurements etc. But the growth in input and output (inputs grew less rapidly than output) suggest that there were labour-saving technological change in the economy.

If international trade can explain the increased demand and wage bill of non-production workers then there would be shift in demand for labour from production worker intensive industries to non-production worker intensive industries i.e., *between* industries. On the other hand, if biased technological change can explain the increased skill demand and skilled wage bill then that would change the demand for production and non-production workers *within* industries. With this view, Berman, Bound and Griliches (1994) used the standard decomposition of increase in non-production fraction of total employment over the periods of 1959 to 1973, 1973 to 1979, and 1979 to 1987. Their findings support the skill-biased technological change in explaining the increased share of non-production employment, as the *within* industry component dominates the *between* industry ones in each period. Hence, international trade cannot explain the skill upgrading in the manufacturing sector in U.S. Since, manufacturing industries alone had over 20% of skill upgrading in 1980s (Murphy and Welch, 1993), if trade and foreign outsourcing can explain only a little of skill upgrading in manufacturing, it is unlikely that they can explain much of it in other sectors.

Using the data of ten developed countries for the period of 1970 to 1990, Berman, Bound and Machin (1997) concluded that pervasive skill-biased technological change (SBTC) is the principal explanation for the increased relative demand for skills. They agreed that the effects of international trade suggested by H-O or Stolper-Samuelson theory of trade, deunionisation, and decreased minimum wages are also responsible for the increased demand for skill. But they maintained that these above mentioned reasons are far from being the principal explanations of wage inequality of skilled-unskilled workers and increased demand for skills.

2.4 Trade and Technology effects in the Australian Labour Market

In recent years, several studies have been undertaken to investigate the causes of increase in the relative demand for skilled-workers in Australia. Borland and Foo (1996) found some empirical supports towards the labour-saving technological change as the main reason of changed employment composition in Australia. They used descriptive method in analysing the employment shares of skilled and unskilled-workers in the manufacturing industries over the period 1952 to 1987. Their findings do not support the view that the increased international trade is responsible for changes in the employment pattern.

Fahrer and Pease (1994) found that the effects of import-substitution and reduction in trade protection on employment are not alarming yet in Australia. They used a more sophisticated decomposition method to analyse the employment pattern changes in manufacturing industries in Australia during the time 1980s to early 1990s. They identified significant negative effects of import-substitution on employment in some subset of industry groups. However, this is not the sole cause of reduced employment share of low-skilled workers in Australia. They further showed that productivity growth (part of which is reflected in technological change) has a significant negative relationship with employment. Murtough, Pearson, and Wreford (1998) found similar effects of productivity growth on labour market in Australia. In a recent study, Laine, Laplagne, and Stone (2000) provided evidence of SBTC having a significant influence on the increased inequality among skilled-unskilled workers in Australia over the past two decades.

Using Granger Causality and non-nested tests on the dynamic models of trade and technology, Karunaratne (1999) revealed that both trade and technology played a role in increasing wage disparity in Australia since 1980s. This is the time when Australia stepped into the globalisation process. His findings from the causality tests also support other causes such as female participation, immigration, and institutional factors like deunionisation etc. as significant contributors to wage disparity.

Gaston (1998) primarily studied the effects of international trade on employment. He found that reductions in effective protection rates have had only a minor effect on sectoral-level employment. Increases in imports appear to be slightly more important in explaining trends in aggregate employment in his work. Covering a period of 1973 to 1992, Gaston (1998) showed that a 5.8 percent growth in imports could explain a 2.1 percent decline in employment in Australian labour market.

The preceding discussion reveals that there have been mixed evidences on the causes of the changing pattern of demand for labour in the developed countries including Australia. There are evidences in favour of both trade and technology as the responsible factors. In most of the cases the technology has been measured as a 'residual' to explain the changes in labour market. Another factor to take into consideration is that the changes in technology can be the result of the pressure from the increased competition from growing international trade. In such a case, part of the effects of technological change on labour demand would come from expanding international trade.

2.5 Policy Options Suggested by Trade and Labour Economists

According to Deardorff (1998) the best policy to restrict the increasing wage inequality should not depend on the cause of the rising wage inequality. Increased trade with developing countries have its costs and benefits to the society. If the social cost of wage differential due to increased international trade were large enough compared to the total gains from trade then restricting trade would be beneficial to society. Same argument is valid for technology. Being a trade economist, Deardorff argued that if trade restriction were the only policy available then it would be the best. But if there were other policy options then those would be preferred to trade restrictions for reducing the skilled-unskilled wage differential. For example an increased trade barrier of, say, 10 percent would reduce the wage of skilled-labour by 15 percent. This trade barrier would be equivalent to a tax of 10 percent on the wages of skilled workers or 15 percent tax on skill-intensive products. Deardorff (1998) argued that in this case tax on skilled wages or on skill-intensive products would be a better policy option than reducing trade by imposing trade barriers. He suggested that the cure of rising wage inequality among the skilled and unskilled workers should not depend on the cause (trade or technology).

Karunaratne (1999) suggested a neo-protectionist policy to restrict imports from developing countries through Voluntary Export Restraints to curtail the adversity of increasing trade and inequality in Australia. He agreed that these policies may cause retaliation of the developing countries resulting in erosion of national and global welfare of the trading partners. His findings also include the skill-biased technological change as a cause behind the increase in the demand for skilled-labour compared to the supply, resulting in increase in skilled-wage and therefore, wage inequality. Hence, he also suggested policies for Australia that would revive the proposals in the National Training Reform Agenda (EPAC, 1995, p.32) and the Job Compact to activate the labour market programs to tackle the long-term unemployment.

The economists who believe that trade is not the main reason of widening wage inequality agree that in future it could cause labour market impacts. Even then they do not support the view of protectionists that trade barriers be increased. They argue that trade makes some people gainers and some losers but trade restrictions will deteriorate the overall economic situation. Subsidising the low skill labours in various countries can be the alternative to protection and thereby helping to stop wage inequality. The weakness of this proposal lies in the fact that the skilled workers may not like to be taxed to finance the subsidy towards the unskilled.

Rising Wage Inequality: Can Factor-Biased Technological Change Explain It? A Case Study of Australia

3.1 Introduction

Since the mid 1970s, Australia's skilled wages fell somewhat steadily relative to unskilled wages. After mid 1980's the trend has reversed and the skilled unskilled wage ratio started to rise. Since then, with the exception of few years, the skilled unskilled wage ratio has been increasing steadily in Australia.

Table 3.1 shows the skilled and unskilled wages in Australia and the wage inequality of some selected years over the period of 1975 to 1996. From the measurement of skilled-unskilled wage ratio, it is found that the wage gap narrowed in the 1970's until

Table 3.1: Wage Inequality in Australia, 1975 to 1996

Year	Skilled Wage ($) (Annual)	Unskilled Wage ($) (Annual)	Wage Inequality
1975	8723	6296	1.39
1979	12805	9303	1.38
1982	17498	12909	1.36
1986	25896	18382	1.41
1988	29137	20498	1.42
1991	34909	24492	1.43
1994	39797	27653	1.44
1996	46748	31266	1.50

Note: There was a change in the ABS occupational classifications in 1986, making time series analysis difficult.
Source: Author's calculation based on ABS data Catalogue No. 6310.0 and 6203.0. Skilled wages have been calculated as weighted average weekly earnings of professionals etc. and unskilled wages have been measured as weighted average weekly earnings of machine workers etc. The weekly wages have been transformed to annual wages. Details of the data have been discussed in the Data Source Section.

early 1980s. From 1986, the wage gap started to rise. Over the period 1982 to 1996, the skilled-unskilled wage ratio increased by about 10.3 percent. Sachs and Shatz (1994) identified a similar trend in the U.S. economy. They found that wage gap narrowed in 1970s, and in the early 1980s it was quite flat. From 1982 up until 1990, the skilled-unskilled wage ratio rose appreciably in the U.S. economy. Freeman (1993) showed that the wage inequality among college graduates and high school educated workers in the U.S. increased by about 30 percent during 1980s and early 1990s. This result has also been confirmed by Sachs and Shatz (1994). Machin (1994) found a similar pattern of rising skilled-unskilled wage ratio in the U.K. In a separate cross country study, Loveman and Blanchflower (1993) identified increase in skilled-unskilled wage inequality in U.K. and Japan but very small increase in France. Contrary to these results, Abraham and Houseman (1993) found no evidence of increase in wage inequality in Germany. Overall, a majority of the studies provide evidence in support of rising wage inequality of the skilled and unskilled workers in different industrialised countries. These evidences led Sachs and Shatz (1994) to conclude that rising wage inequality between skilled and unskilled workers has been a global rather than a local phenomenon.

Over the last few decades, rising wage inequality among the skilled and unskilled workers, especially in developed countries has become a major concern among the economists and policy makers. One of the major explanations for the increasing wage differential among skilled and unskilled workers along with the rising ratio of skilled-unskilled employment has been put forward in terms of skill-biased technological change (Lawrence and Slaughter, 1993; Krugman, 1994).

Skill-biased technological change may increase the demand for skilled labour for two reasons. Firstly, the increase in relative productivity will increase the return to skilled workers. Secondly, the unskilled workers are unable to adapt to the use of new technology. Recent technological advancements are mostly unskilled labour saving and could provide another simple explanation of increasing skilled demand (Dawkins and Kenyon, 2000). To date, there is yet to be a consensus on an explicit economic way to compute the technological change or to interpret skill-biased technological change (Krusell, Ohanion, Ríos-Rull and Violante, 1997). Since skill-biased technological change is mainly accused of being responsible for the trend of rising wage inequality, this chapter discusses how such technological change affects the wage ratio of skilled and unskilled workers. This chapter also examines the impacts on skilled-unskilled wage ratio if the technological change were skill-biased, unskilled labour-biased or capital-biased and compares these effects with the observed skilled-unskilled wage ratio.

In this chapter, a theoretical framework has been developed that provides a simple but explicit way to measure not only the skill-biased technological change but also different factor-biased technological change separately in terms of observable variables. This framework has been used to compute the variation in wage ratio of skilled-unskilled workers that can be explained by the changes in different factor-biased technological changes over the twenty-year period for Australia (1975 to 1995). After calculating the wage ratio of skilled and unskilled workers using different factor-biased technological change, the calculated wage ratio and the observed skilled-unskilled wage ratio have been compared. From the comparisons it can be examined which of the factor-biased technological change can account for the trends of observed rising wage inequality in Australia.

One important assumption adopted in this study is capital-skill complementarity. This assumption implies that the elasticity of substitution between capital and unskilled labour is higher than the elasticity of substitution between capital and skilled labour. With increase in the capital stock and in the supply of skilled labour, the capital-skill complementarity may be able to explain the rise in the return to skilled relative to unskilled workers. This may also explain, at least to some extent, the rising returns to skill with increased supply of skills, rather than a fall in the return to skills (Fallon and Layard, 1975; Krusell, Ohanion, Ríos-Rull, and Violante, 1997). Capital-skill complementarity plays a crucial role in the choice of values of substitution parameters in this study. Another assumption of this study is the ease of substitutability between the skilled and unskilled workers and between capital and unskilled workers.

Given the importance of the connection between capital, skilled and unskilled labour, a three-factor aggregate production function, rather than a two-factor production function, has been used in this chapter. The objective of this study is to evaluate which of the three factor-biased technological changes is important in accounting for changes in economy wide aggregate wage inequality in Australia over the 20 year period, from 1975 to 1995. The three-factor production function allows for varying elasticities of substitution between capital and skilled labour and between capital or skilled labour and unskilled labour, separately. It also allows for different elasticities of substitution between skilled and unskilled workers. With the assumption of competitive market[1], factor prices are the values of the marginal products of the factors used in the production process. For the values of the parameters of substitution elasticities between capital and skilled labour and between capital (both the physical capital and human capital or skilled labour) and unskilled labour, the existing estimates of elasticity of substitution have been used. After choosing the parameters, the skilled and unskilled wages and their ratios have been computed. The calculated skilled-unskilled wage ratios, varying only one technological change (unskilled-labour, skilled labour or capital biased or augmenting) at a time and normalising the others to unity, have been compared with observed skilled-unskilled wage ratios in the economy.

The rest of the chapter is organized as follows: Section 3.2 provides a general discussion of different types of technological change. Sections 3.3 and 3.4, defines and explains the process of parameters chosen and the data used for the observed variables, respectively. The results of the study have been analysed in section 3.5, followed by a sensitivity analysis of the results. The chapter ends with a brief summary and some concluding remarks provided in section 3.6.

3.2 Definitions and Methodology

Allen (2001, pp. 445-446) described the fact that 'technological change' can be defined in two different meanings. In his own words:

'The standard economic definition (of technological change) is the ability to produce more output with the same amount of inputs, usually the consequence of better knowledge or organization. The appropriate measure of this type of technological change is total factor productivity (TFP) growth, the growth in output that cannot be explained in terms of changes in the quantity or quality of inputs. This measure is

[1] There is a limitation of the assumption of competitive factor markets for Australia. It is due to the fact that Australian labour market has been extensively regulated by the government and this regulation has changed over time. Hence, for Australia the factor prices may not be the values of the marginal products of the factors used as assumed in the calculations in this chapter.

always problematic in empirical work because it is by definition a residual and questions about whether the data have been completely purged of all changes in input quantity and quality never can be completely resolved.

Alternatively, technological change can mean a change in equipment and job requirements. The substitution of personal computers, software, and printers for typewriters would qualify as a change in technology under this definition, but not necessarily under the former.'

In this chapter, the first meaning of the technological change mentioned by Allen (2001) has been used to analyse the impacts of technological change in explaining rising wage inequality among the skilled and unskilled workers. The second meaning of technological change has been used to analyse the impacts of technological change on the labour market in Chapter Five of the dissertation.

Before discussing the methodology adopted in this study, it would be useful to provide a brief overview of concepts of different types of technological change. Much of the definitions of different types of technological change below have been presented following Neher (1971).

Technological change is often defined as the total factor productivity growth, measured as the amount of output growth not accounted for by the increase in the quantity of all the inputs used in the production process. As the literature suggest, total factor productivity growth measures technological change when constant returns to scale (CRS[2]) are exhibited and there is no inefficiency in the production process. In other words, if technological change prevails in an economy, then by using the same level of capital and labour (assuming there are only two factors of production) more output than before can be produced, or the same level of output could be produced with less of both or at least with less of one input. With technological change, an economy experiences an upward shift of its production function (Solow, 1957). Technological change can be neutral or biased. When technological change is biased, the marginal productivity of the factor inputs changes at different rates. Neutral technological change occurs when the marginal productivity of all the factors change at the same rate. There are usually three measures of technological change, viz. technological change in Hicks' sense, Harrod's sense and Solow's sense. As technological change in Harrod's sense and Solow's sense

[2] The assumption of CRS is required for TFP growth to be a measure.

are not relevant in this context, this study mainly focuses on the Hicks-neutral and Hicks-biased technological changes.

In the production process, if the marginal product of capital (MP_K) and the marginal product of labour (MP_L) (or in general, marginal products of all inputs) increase in the same proportion due to technological change alone then such technological change would be defined as Hicks neutral. In other words, technological change is Hicks neutral if the ratio of marginal product of labour to marginal product of capital remains unchanged at any given level of capital-labour ratio, *K/L*. On the other hand, the Hicks biased technological change can be denoted as

$$\gamma = \theta_K - \theta_L \tag{3.1}$$

where, γ is the bias in the technological change and θ_K and θ_L are the rates of changes in marginal product of capital and labour, respectively.

If the increase in marginal product of capital is equal to the increase in marginal product of labour then this indicates neutral technological change taking place in the relevant production process. Technological change is called capital augmenting or labour saving if for any given level of capital-labour ratio, the marginal product of capital increases more than the marginal product of labour as a result of technological change. Clearly, in such a situation, the proportional change in marginal product of capital would be greater than the proportional change in marginal product of labour (that is, $\theta_K > \theta_L$). The firms would hire more capital relative to labour in their production at the given level of factor prices (that is, at fixed wage rate, w and rental rate of return, r). It is because the marginal product of capital has risen relative to that of labour at the original capital-labour ratio. If the marginal product of labour rises by more than marginal product of capital at a given capital-labour ratio then technological change is capital saving or labour using. In a closed economy, the capital-labour ratio is constant at any given time and technological change cannot change the factor proportions. Instead, the capital using or labour saving technological change induces firms to bid up the return to capital relative to wages. The opposite would occur if the technological change were labour using or capital saving.

Hicks-neutral technological change does not raise the return to skill and therefore, cannot cause rising wage inequality. Hence, the major concern of this study is not Hicks neutral technological change but Hicks-biased technological change. An algebraic approach of both neutral and biased technological change in Hicks' sense is given below. When the technological change is Hicks neutral the production function can be written as

$$Y = A(t)G(K,L)$$

Or (3.2)

$$y = A(t)g(k)$$

where, t denotes time, $A(t)$ indicates technological change over time and $y = Y/L$ and $g(.) = G(K/L, 1)$.

The marginal products of capital and labour (which are also the input use conditions of the model) can be presented as

$$r = A(t)g'(k) \tag{3.2.1}$$

and

$$w = A(t)[g(k) - k.g'(k)] \tag{3.2.2}$$

To find θ_K and θ_L, equations (3.2.1) and (3.2.2) are partially differentiated with respect to time and then partial derivatives have been expressed in proportion.

$$\begin{aligned} &\frac{\delta r}{\delta t} = g'(k).\dot{A} \\ &\frac{1}{r}.\frac{\delta r}{\delta t} = \frac{1}{A}.\frac{dA}{dt} = \frac{\dot{A}}{A} = A* \\ &\theta_K = A* \end{aligned} \tag{3.2.1A}$$

Similarly, for the marginal product of labour,

$$\theta_L = A*.$$

Thus, $\gamma = \theta_K = \theta_L = A* - A* = 0$.

Here, the dot superscript implies first derivative over *time* and * denotes the rate of change through time.

To give a clearer picture of Hicks neutral technological change, let us suppose, A is equal to 100 at a point in time, and rises to 105. Then $A^* = 0.05$ or 5 percent. With no change in the capital-labour ratio, $k=K/L$, both w and r rise by 5 percent.

To elaborate Hicks biased technological change a more general functional form of the production function has been chosen

$$Y = F(K, L, t) \tag{3.3}$$

This production function is assumed to be homogenous of degree one in capital, K and labour, L, but not in time, t. That is, constant returns to scale and perfect competition in the factor input market prevail. In other words, $Y = rK + wL$, and $P = MC = AC = 1$.

The marginal product of capital, and labour, which are also the input use conditions, are

$$r = f_K(k,t)$$
and
$$w = f(k,t) - k.f_K(k,t)$$

The rates of change of returns to capital and labour would be

$$\begin{aligned} r* &= -\frac{1-a}{\sigma}k* + \frac{1}{r}\frac{\delta r}{\delta t} \\ &= -\frac{1-a}{\sigma}k* + \theta_K \end{aligned} \tag{3.3.1}$$

and

$$w* = \frac{a}{\sigma}k* + \theta_L \tag{3.3.2}$$

where a and (1-a) are the share of capital and share of labour to total output, respectively. σ is the elasticity of substitution. θ_K and θ_L are the rates of changes in marginal products of capital and labour, respectively, over time. Or, in other words, these are the capital-biased and labour-biased technological changes, respectively.

The total rate of change in output over time is denoted by $\theta = a\theta_K + (1-a)\theta_L$.

The bias of measurement of technological change in Hicks' sense is given by $\gamma = \theta_K - \theta_L$. Combining these two definitions we get, $\theta_K = \theta + (1-a)\gamma$ and $\theta_L = \theta - a\gamma$.

Substitution of the values of θ_K and θ_L in the rates of change of r and w yields the following expressions

$$r* = -\frac{1-a}{\sigma}k * + \theta + (1-a)\gamma \qquad (3.4.1)$$

and

$$w* = \frac{a}{\sigma}k * + \theta - a\gamma \qquad (3.4.2)$$

From the equations (3.3.1) and (3.3.2) it is observed that with capital deepening ($k* > 0$), wage increases and interest rate goes down. Increase in output due to technological change ($\theta > 0$) raises both the r and w. If the technological change is capital deepening or labour saving ($\gamma > 0$), the interest rate rises more than wages than if the technological change is neutral. In other words, if technological change is neutral, i.e., $\gamma = 0$, the wage-rental ratio does not change ($w * - r * = 0$) at a constant capital labour ratio ($k * = 0$). This is a decade old standard theory, but as Krugman (2000) points out, this theory has become relevant today due to the evidence of strong skill-biased technological change in the developed countries.

Firstly, considering a Cobb-Douglas production function, the effect of technological change on the wage-rental ratio has been illustrated below. The Cobb-Douglas production function is

$$Y = (AK)^a (BL)^{1-a} \qquad (3.5)$$

where, A and B are the efficiency parameters of capital and labour, respectively. a is a positive number representing the share of capital in output and $(1-a)$ is the share of labour in output. The production function follows constant returns to scale (implying perfect competition in factor input markets) and shares of capital and labour are fixed in the production process. Hence, the returns to factor inputs equal their marginal products. *Y, K* and *L* have the same definitions as used before.

The return to capital in Cobb-Douglas production function would be

$$
\begin{aligned}
r &= \frac{\delta Y}{\delta K} = (BL)^{1-a} aA^{a} K^{a-1} \\
&= a(AK)^{a} (BL)^{1-a} . \frac{1}{K} \\
&= a . \frac{Y}{K}
\end{aligned}
\tag{3.5.1}
$$

Similarly, the return to labour would be

$$
\begin{aligned}
w &= \frac{\delta Y}{\delta L} = (AK)^{a} (1-\alpha) B^{1-a} L^{1-a-1} \\
&= (AK)^{a} (BL)^{1-a} (1-a) . \frac{1}{L}
\end{aligned}
\tag{3.5.2}
$$

The rate of change of interest rate, *r*, and the rate of change of wage, *w*, over time have been given as

$$
r* = a \frac{Y*}{K*} \tag{3.5.3}
$$

and

$$
w* = (1-a) \frac{Y*}{L*} \tag{3.5.4}
$$

The effect of technological change on wage-rental ratio in this production function would be

$$\frac{w*}{r*} = \frac{(1-a)\dfrac{Y*}{L*}}{a.\dfrac{Y*}{K*}} \qquad (3.5.5)$$

$$= \frac{(1-a)}{a} \cdot \frac{K*}{L*}$$

Holding the capital-labour ratio constant ($K*/L* = 0$), the rate of change in the wages rental ratio would be zero. In other words, in a Cobb-Douglas world where the elasticity of substitution (σ) equals unity, the wage-rental ratio remains the same with any type of technological change (for example, labour-augmenting or capital-augmenting technological change). That is, all types of technological change have Hicks-neutral effect on factor incomes with Cobb-Douglas type of production function.

In search of the effects of different factor-biased technological change on the rising wage differential among skilled and unskilled workers, a two-stage Constant Elasticity of Substitution (CES) production function has been used in this study following Fallon and Layard (1975) and Krusell, Ohanion, Rios-Rull and Violante (2000). A CES production function of the following form has been considered

$$Y = A[(\delta_Z Z)^{\rho} + (\delta_L \widehat{L})^{\rho}]^{\frac{1}{\rho}} \qquad \rho \leq 1 \qquad (3.6.1)$$

where,

$$Z = [(\delta_K \widehat{K})^{\nu} + (\delta_H \widehat{H})^{\nu}]^{\frac{1}{\nu}} \qquad \nu \leq 1. \qquad (3.6.2)$$

In the above two equations, *Y, K, L* and *H* denote income, physical capital, unskilled labour and human capital or skilled labour, respectively. $\widehat{K} = \tau_K K, \widehat{H} = \tau_H H$, $\widehat{L} = \tau_L L$ and τs are the technical coefficients of the respective variables. δ, ρ, and ν are the parameters. ρ and ν are the substitution parameters that determine the elasticity of substitution between unskilled workers and capital or skilled workers and between capital and skilled workers, respectively. δ is the parameter that governs the income shares and A is the efficiency parameter. It has been assumed that the relevant production process exhibits CRS, which also implies that perfect competition prevails in the factor input market and the factors are paid according to their marginal products.

The main objective of this study is to find out the possible changes in rates of return to skilled and unskilled labour (i.e., skilled and unskilled wages) due to changes in the factor efficiency parameters, which can also be termed as factor-biased or factor-augmenting technological change. The studies that give the evidences of skill-biased technological change have been mostly done on the U.S. economy (for example, Fallon and Layard, 1975; Bound and Johnson, 1992; Krusell, et al., 2000. The evidence from the U.S. economy shows that there has been a widening of wage inequality caused by the increase in the relative demand for skilled workers.[3] There have not been too many studies examining the factors behind the rising wage inequality along with the rise in relative demand for skilled workers in Australia. However, a few studies have been conducted in recent years with varying results. Borland and Foo (1996) found that intra-industry effects could explain 90 percent of the changes in employment shares of production (unskilled) and non-production (skilled) workers in manufacturing industry in Australia over the period, 1978 to 1987.[4] Berman, Bound and Machin (1997) also found evidence of intra-industry shifts in the composition of employment in Australian manufacturing industry over the period 1970-1990, along with other OECD countries. These findings point towards non-neutral technological change as the possible cause of rising wage inequality. Fahrer and Pease (1994) and Murtough, Pearson and Wreford (1998) showed that the increase in labour-productivity (part of which may be the technological change) has been the cause of shift in demand for skilled workers. Some other studies (for example, Gaston, 1998 and Pappas, 1998) also found the evidence of some skill-biased technological change in Australia.

The next task would be to explain the cause behind the factor-augmenting technological change. One reason of skill-biased technological change could be the increased competition from growing international trade. Dawkins and Kenyon (2000) analysed a number of theoretical and empirical studies that show that increased openness induced

[3] A comprehensive literature review on wage inequality is included in the literature review (Chapter Two).
[4] This type of study assumes that changes in international trade or in sector-biased technological change would end up by causing inter-industry shift in employment. But intra-industry shift in employment would be the result of skill-biased technological change.

transmission of skill-biased technological change in the developed countries. These studies include Grossman and Helpman (1991), Coe and Helpman (1995), Eaton and Kortum (1996), and Coe, Helpman and Hoffmaister (1997).

In the process of explaining how international trade can induce biased technological change, Dawkins and Kenyon (2000, p.13) give the following comments:

'If changes in the terms of trade allow skilled workers to augment human capital at a greater rate than less skilled workers, because skilled workers are more mobile between sectors (and therefore suffer fewer interruptions to human capital accumulation), then increased exposure to international trade will affect wage-differentials based on skill.'

There have been few critics of skill-biased technological change, who are mainly trade economists. Among them Leamer (1994) claims that the whole issue of factor-biased technological change to explain the wage inequality is unnecessary and irrelevant. According to Leamer and other critics of factor bias interpretation of wage inequality, if anything matters based on trade theory it should be the sector bias not the factor bias of technological change.

Paul Krugman, in one of his recent papers (Krugman, 2000) explained how the critics of factor-biased technological change could be wrong. Firstly, Krugman ran a feasibility test of the technology story by using the U.S. wage and productivity data. The findings were in favour of factor-biased technological change, i.e., with reasonably large elasticity of substitution the productivity growth in the U.S. had been found large enough to be consistent with a factor-bias explanation of wage changes. Secondly, Krugman showed, both in one sector and multiple sector models, assuming that the technological change occurs simultaneously in the world, skill-biased (or more generally factor-biased) technological change in any sector increases the skill-premium. On the other hand, Hicks-neutral technological change in skill-intensive sector does not raise the skilled wages.

In his exercise, Krugman (2000) started with two assumptions, first, utility is Cobb-Douglas in nature, implying a constant share of income spent on each good and second, the production function is a fixed proportion production function. This is to mean that allocation of factors in each sector is independent of factor prices or prices of goods. He also showed that when these assumptions are relaxed factor-biased technological change still raises the skill-premium. Krugman (2000, p.7) then concluded as follows:

'Those trade economists who have asserted that factor price trends depend only on the sector of technical change, and not at all on the factor bias of that change, have therefore got it almost exactly the wrong way around. When technological change occurs in a large economy, or occurs simultaneously in a number of economies which are collectively able to affect world prices, skill-biased progress does indeed tend to raise the skill-premium. Meanwhile, the sectoral bias of technical change has an effect which is ambiguous if it is there at all.'

For this chapter the expressions for the returns to factors of production have been derived from the two-stage CES production function ((3.6.1) and (3.6.2)). Given the assumption of constant returns to scale and perfect competition in the factor input markets, the factor inputs will be paid in accordance with their marginal productivities. So, the returns to unskilled labour, human capital or skilled-workers and physical capital, respectively, can be given as follows

$$\frac{\Delta Y}{\Delta L} = w_L = \tau_L (A\delta_L)^{\rho} \left(\frac{Y}{\hat{L}}\right)^{1-\rho} \tag{3.7.1}$$

$$\frac{\Delta Y}{\Delta H} = w_H = \tau_H (A\delta_Z)^{\rho} (\delta_H)^{\nu} \left(\frac{Y}{Z}\right)^{1-\rho} \left(\frac{Z}{\hat{H}}\right)^{1-\nu} \tag{3.7.2}$$

and

$$\frac{\Delta Y}{\Delta K} = r_K = \tau_K (A\delta_Z)^{\rho} (\delta_K)^{\nu} \left(\frac{Y}{Z}\right)^{1-\rho} \left(\frac{Z}{\hat{K}}\right)^{1-\nu} \tag{3.7.3}$$

The growth of the rate of return to skilled and unskilled labour is the logarithm of the ratio of the return to skilled and unskilled labour, ($\ln(w_H / w_L)$), which is

$$\ln\left(\frac{w_H}{w_L}\right) = \ln\left(\frac{\tau_H}{\tau_L}\right) + \rho \ln\left(\frac{\delta_Z}{\delta_L}\right) + (1-\rho)\ln\left(\frac{\hat{L}}{Z}\right) + \nu \ln(\delta_H) + (1-\nu)\ln\left(\frac{Z}{\hat{H}}\right) \tag{3.8}$$

Let us now consider the effect of different types of factor-biased technological change on the growth of the ratio of wages between skilled and unskilled workers. If it is assumed that the technological change in the economy has been unskilled-labour augmenting, which implies that $\delta \ln \tau_K = 0$ and $\delta \ln \tau_H = 0$, then the rate of change of the ratio of the wage of human-capital to labour would be

$$\frac{\Delta \ln\left(\frac{w_H}{w_L}\right)}{\Delta \ln \tau_L} = \frac{\Delta\left(\ln \tau_H - \ln \tau_L + (\rho - \nu)\ln Z + (1-\rho)\ln \widehat{L} + (\nu - 1)\ln \widehat{H} + \rho \ln\left(\frac{\delta_Z}{\delta_L}\right)\right)}{\Delta \ln \tau_L}$$
$$= -1 + (1-\rho)$$
$$= -\rho \tag{3.9.1}$$

This is the rate at which the wage inequality among the skilled and unskilled workers would increase if the technological change is unskilled-labour augmenting. The above equation tells that the wage ratio between skilled labour to unskilled labour would grow at the rate of the negative of the substitution parameter among the skilled and unskilled workers or capital and unskilled workers when the technological change is unskilled-labour augmenting[5]. If the elasticity of substitution is equal to one, i.e., $\sigma = 1$, then there will be no change in the ratio of the rates of return with the unskilled labour-augmenting technological advancement. In other words, if the production function is of Cobb-Douglas type then there will be no change in wage disparity due to unskilled labour-augmenting technological change.

Similarly, for the skilled labour-augmenting and capital-augmenting technological change, the rate of change in the ratio of the return to skilled labour to unskilled labour would be

$$\frac{\Delta \ln\left(\frac{w_H}{w_L}\right)}{\Delta \ln \tau_H} = \frac{\Delta\left(\ln \tau_H - \ln \tau_L + (\rho - \nu)\ln Z + (1-\rho)\ln \widehat{L} + (\nu - 1)\ln \widehat{H} + \rho \ln\left(\frac{\delta_Z}{\delta_L}\right)\right)}{\Delta \ln \tau_H}$$
$$= 1 + (\rho - \nu)\frac{\Delta \ln Z}{\Delta \ln \tau_H} + (\nu - 1)$$

[5] The elasticity of substitution between unskilled-labour and capital and unskilled-labour and skilled-labour is given by $1/1-\rho$ and therefore, $-\rho$ is equal to $1-\sigma/\sigma$.

$$= (\rho - \nu)\frac{a_H}{a_K + a_H} + \nu \qquad (3.9.2)$$

and

$$\frac{\Delta \ln\left(\frac{w_H}{w_L}\right)}{\Delta \ln \tau_K} = \frac{\Delta\left(\ln \tau_H - \ln \tau_L + (\rho - \nu)\ln Z + (1-\rho)\ln \widehat{L} + (\nu - 1)\ln \widehat{H} + \rho \ln\left(\frac{\delta_Z}{\delta_L}\right)\right)}{\Delta \ln \tau_K}$$

$$= (\rho - \nu)\frac{a_K}{a_K + a_H} \qquad (3.9.3)$$

where a_K and a_H represent the share of capital and skilled labour to total output, respectively.

The equations of the factor shares of capital, skilled-labour and unskilled labour to output, respectively, are as follows. Note that these are also the elasticities of output with respect to various factor inputs.

$$\begin{aligned} a_K &= r_K \frac{K}{Y} = \frac{r_K}{\tau_K}\frac{\widehat{K}}{Y} \\ &= \left(\delta_Z A \frac{Z}{Y}\right)^{\rho}\left(\tau_K \delta_K \frac{K}{Z}\right)^{\nu} \end{aligned} \qquad (3.10.1)$$

$$\begin{aligned} a_H &= w_H \cdot \frac{H}{Y} = \frac{w_H}{\tau_H}\frac{\widehat{H}}{Y} \\ &= \left(A\delta_Z \frac{Z}{Y}\right)^{\rho}\left(\tau_H \delta_H \frac{H}{Z}\right)^{\nu} \end{aligned} \qquad (3.10.2)$$

and

$$\begin{aligned} a_L &= w_L \cdot \frac{L}{Y} = \frac{w_L}{\tau_L}\frac{\widehat{L}}{Y} \\ &= \left(A\delta_L \tau_L \frac{L}{Y}\right)^{\rho} \end{aligned} \qquad (3.10.3)$$

Equation (3.9.2) shows that the effect of skilled labour-augmenting technological change would increase the ratio of the wages of skilled labour to that of unskilled-labour only if, $\rho > \nu$. In other words, the elasticity of substitution between skilled labour and unskilled labour is greater than the elasticity of substitution between capital and skilled labour. The direct elasticities of substitution in the two level CES production function can be written as

$$\sigma_{HK} = \frac{1}{1-\nu}$$

and (3.11)

$$\sigma_{LK} = \sigma_{HL} = \frac{1}{1-\rho}$$

With the assumption of capital-skill complementarity, that is, the elasticity of substitution between L and K or between L and H is greater than the elasticity of substitution between H and K, the skilled labour-augmenting technological change would widen the gap between skilled and unskilled wages (from the equation (3.9.2)).

3.3 Descriptions and Sources of Data

Standard definitions of macroeconomic variables have been adopted for empirical analysis of this chapter. For the variable national income Y, GDP at market price has been used. The data on Australian GDP for the years 1975 to 1995 have been obtained from Australian Bureau of Statistics (ABS) Catalogue No. 5206.0. These values of GDP expressed in current prices have been transformed into 1989-90 constant prices using GDP deflator with the base year of 1989-90. The series of GDP deflators has also been available from ABS time series spreadsheets.

Capital (K) has been defined as end year net capital stock. These data have been available in ABS catalogue No. 5221.0, over the period from 1975 to 1995. The nominal values of capital stock have been converted to 1989-90 constant prices using the price deflator for non-dwelling construction and equipment available from ABS.

In this chapter wage inequality has been measured as the ratios of average weekly earnings of skilled and unskilled workers in Australia. Wages of skilled workers have been defined as weighted[6] average weekly earnings of the professional, technical, administrative, executive and managerial workers of the Australian Standard Classification of Occupation (ASCO) groups classified until the year 1985. On the other hand, until 1985, wages of unskilled workers comprise of the average weekly earnings of the clerical, sales, labourers and other low skilled workers of ASCO groups. With changed ASCO classification after 1985, wages of the skilled workers have been defined as the average weekly earnings of the workers who fall into the categories of professional, manager, administrator and para-professionals. Similarly the unskilled workers' wage comprise of the average weekly earnings of the workers who are included in the categories of clerks, sales persons, machine workers, labourers and other workers who require less skill in their occupation than the above mentioned occupations of the skilled workers. These weekly wages then have been transformed to annual wages.[7] One weakness of the calculations of skilled wages is the inclusion of the managerial wages. There is a possibility that a large proportion of the wages of managers may be tied to stock market performance of firms rather than to individual performance. In that case, the wage setting of managers will be different to that of other skilled workers. But this weakness is minimised by giving the weights to the earnings of each group by the share of employment to total employment of that group. The wages for the skilled and unskilled workers have been taken from ABS Catalogue No. 6310.0: Mean Weekly Earnings of all Employees in Major and Minor Occupation groups. This is the only source where the earnings by occupation for the whole time series have been available at a reasonably consistent basis. The weighted averages of the weekly earnings of all sub-categories have been used as wage per person and the weekly earnings have been transformed into yearly wages. The real wages have been calculated by dividing the nominal wages by Consumer Price Index at 1989-90 prices. Wage share of GDP at factor cost has been taken from ABS Catalogue No. 5204.0 of 1995-96.

To construct the skilled and unskilled workforce similar categories has been used as described above for the skilled and unskilled wages. The data for skilled and unskilled

[6] Share of employment in each group to total employment have been used as weights.

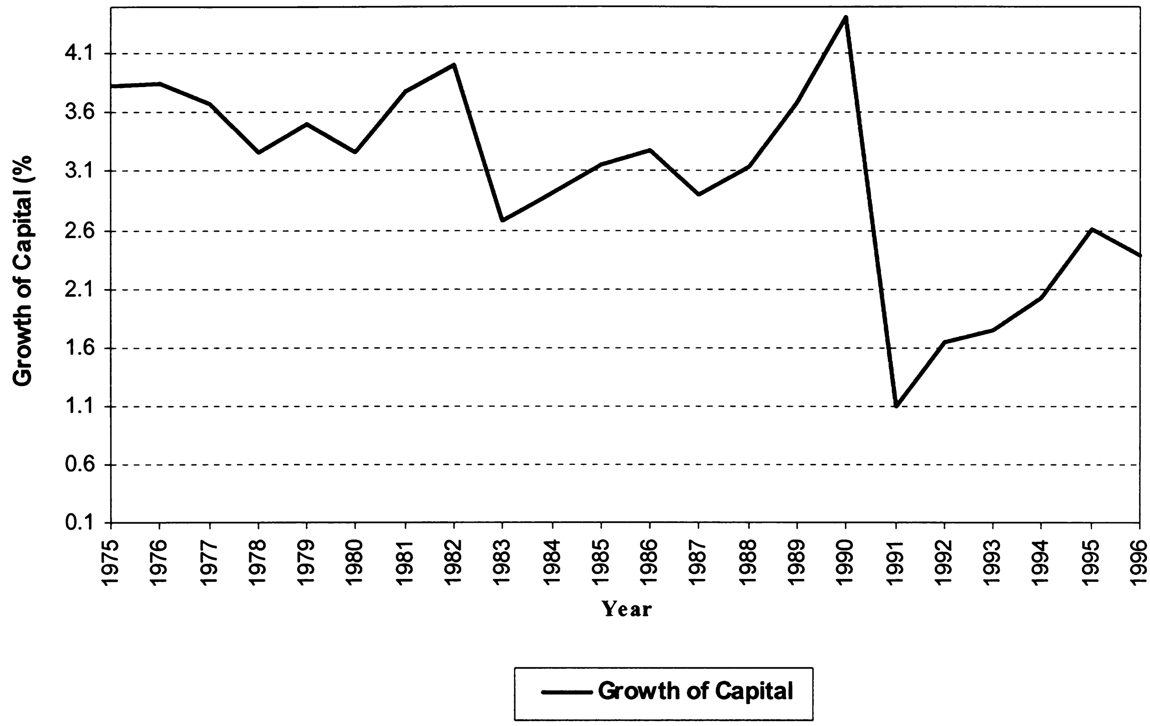
[7] The redefinition of occupational groups in 1986 by ABS has made any time series analysis difficult using these data.

labour have been obtained from ABS Catalogue No. 6203.0, Employed Persons by Occupation. Similar definitions of skilled and unskilled workforce and wages of Australia have been used by some researchers such as Karunaratne (1999), Fahrer and Pease (1994). Karunaratne (1999) used general managers and business professionals as skilled workers; and machine operators, trade assistants and factory hands as unskilled workers. Fahrer and Pease (1994) used business professionals as a proxy for wages of high skilled workers and machine operators as a proxy for low skilled workers. The concern of this chapter is the wage inequality not for any specific industry, but for the economy wide aggregate level. Hence, all categories in the occupation group used by the ABS in defining the skilled and unskilled workers and their wages have been used in this chapter. As a consequence, the increase in wage inequality may not be as large as that found in any particular sector or industry.

Figure 3.1 below presents the growth of net (real) capital stock over the period of 1975 to 1996. Figure 3.2 depicts the ratio of the skilled and unskilled employment of Australia over the period of 1974 to 1996. Lastly, Figure 3.3 represents the skilled-unskilled wage ratio at macroeconomic level for Australia over the same period as Figure 3.2.

Summarising the historical changes in the quantities of the capital, skilled labour, and unskilled labour input, it has been found that the capital stock in Australia grew at a rate of 3 percent on average per year over the period 1975 to 1996. This has been illustrated in Figure 3.1.

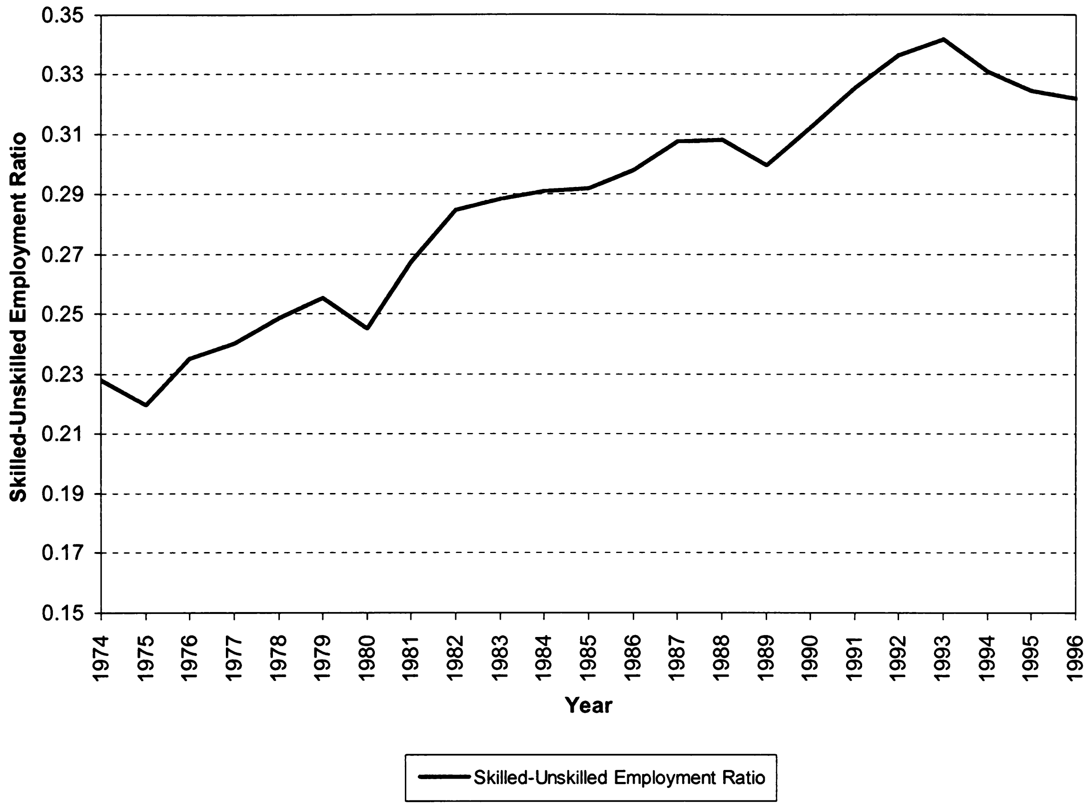
Figure 3.1: Growth of Capital (%), 1975-1996



Source: Author's calculations using the data on real net capital stock provided by ABS in catalogue No. 5221.0

Figure 3.2 presents the ratio of skilled to unskilled labour force in Australia from 1974 to 1996. The figure clearly shows that there has been a large increase in the skilled-unskilled employment ratio in Australia over the period. There have been some years when the skilled-unskilled employment ratio fell relative to the previous years. Overall, the skilled-unskilled employment ratio has increased by 45 percent over the concerned period.

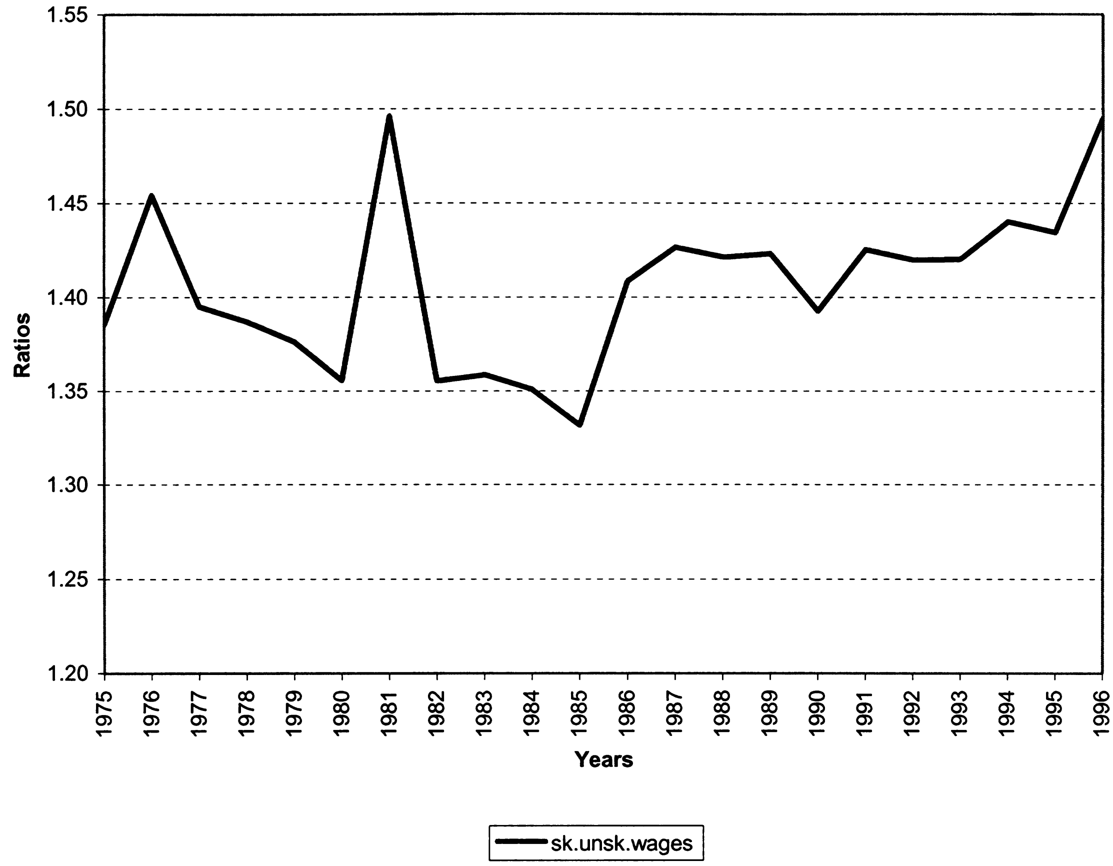
Figure 3.2: Skilled-Unskilled Employment Ratio, 1974 to 1996



Source: Author's calculations using data of employment in different ASCO groups available from ABS Catalogue No. 6203.0
Note: Details of skill classification have been discussed in the Data Description section above.

However, the relative wage paid to the skilled workers has not declined in Australia over the period. It can be seen from the Figure 3.3 that the skilled-unskilled wage ratio mainly decreased over the years 1975 to 1985 with exceptions in 1976 and 1981 when it showed some sharp increase. After 1985, the wage ratio started to increase with some fluctuations until 1996. Skilled-unskilled wage ratio has increased by around 8 percent from 1974 to 1996. The fluctuations in skilled and unskilled wage ratio over the period of beginning of 1980s to mid 1980s should be interpreted cautiously. There could be different reasons for the fluctuations. One of them could be cyclical movements of the economy. This is also the time when the world experienced the skill-biased technological changes. Also, for Australia this is the time when the protections given to domestic industries from foreign competition have been reduced. The important phenomenon to notice here is that both the skilled-unskilled employment ratio and the skilled-unskilled wage ratio have been increasing over these two decades in Australia.

Figure 3.3: Wage Ratios of Skilled-Unskilled Workers, 1975-1996



Source: Author's calculations using skilled and unskilled average weekly wages available from ABS Catalogue No. 6310.0. *Note*: The classifications of skilled and unskilled wages have been discussed in Data Description section above in detail.

3.4 Defining the Parameters for Calibration

In this chapter, the Hicks neutral technological change has been calculated using different values of parameters in a two-stage CES production function. Then keeping the neutral technological change constant at its initial level, different factor-biased technological changes, one at a time (these are the calculated TFP growth with different factor-biased technological changes), have been calculated. Using the calculated TFP growth with different factor-biased technological changes the skilled and unskilled wages have been calculated and compared with the actual or observed skilled-unskilled wage ratios.

The values of the parameters and shares of different factor inputs have been chosen as follows. The share of physical capital, human capital and labour have been given by $a_K = r_K.K/Y$, $a_H = w_H.H/Y$, and $a_L = w_L.L/Y$, respectively. These are also the elasticities of output with respect to the corresponding factor inputs, where, $r_K = \Delta Y/\Delta K$, $w_H = \Delta Y/\Delta H$ and $w_L = \Delta Y/\Delta L$.

The shares of wage bill of skilled and unskilled workers have been chosen as the actual economy wide shares of wage bill of skilled and unskilled workers in GDP respectively, which have been estimated by ABS and averaged over time. With the assumption of constant return to scale, ($a_H + a_L + a_K = 1$), the average wage share of GDP has been around 0.6 for the period 1975 to 1995-96. Similarly, the share of capital has been 0.4. The total wage share in total GDP has been divided between the share of skilled workers and share of unskilled workers. In this process, the averages of the share of skilled and unskilled wages to GDP have been calculated. The share of skilled wages to GDP has been steadily increasing over time. On average, the ratio of wage share of unskilled labour to GDP and skilled labour to GDP has been 2:1 from 1975 to 1995/96, over a period of 20 years. Accordingly, the estimated wage share has been divided as 0.4 and 0.2 as wage share of unskilled labour and wage share of skilled labour respectively. This has given, $a_K = 2a_H$ and $a_K = a_L$.

Initially, the factor biased technological change has been normalised to one, i.e., $\tau_i = 1$. This assumption of normalisation of the technical efficiencies has been relaxed afterwards, one at a time. The total distribution shares of income equals one and hence, $\delta_K + \delta_H = 1$ and $\delta_Z + \delta_L = 1$ (from equations (3.6.1) and (3.6.2). Setting, $\delta_H = 1 - \delta_K$, $\delta_L = 1 - \delta_Z$ and $a_K = 2a_H$, have given, $\delta_K K = 2^{1/\upsilon}\,\delta_H H$. Hence, it has followed from the factor share equations stated above that $\delta_K = cH/(cH+K)$ where the $c = 2^{1/v}$, a constant.

Similarly, setting $a_K = a_L$, from the factor share equations we get, $\delta_L L = \delta_Z Z[\delta_K K/Z]^{v/\rho} = \delta_Z Z\theta$, where, $\theta = [\delta_K K/Z]^{v/\rho}$. If $\delta_Z = 1 - \delta_L$ then $\delta_L = Z\theta/(L+Z\theta)$. Thus given the average values of K, H and L, the parameter values of δ_K, δ_H and δ_L have been derived.

To perform the experiment, the substitution parameters, ρ and v, should also be defined. To choose the values of these substitution parameters, the estimates of substitution parameters in the existing literature have been exploited. A number of studies have estimated elasticities of substitution between capital and skilled or unskilled labour using different functional forms, techniques and data. Hamermesh (1993) summarised many of these studies. Rosen (1968), Griliches (1969), Berndt and Christensen (1974), Fallon and Layard (1975), Denny and Fuss (1977) and Brown and Christensen (1981) found the evidence of capital-skill complementarity which have been reported in Krusell et al. (1997). Krusell et al. (1997) also suggested that many of the estimated elasticities of substitution between unskilled worker and capital range between 0.5 and 3. Krusell et al. (1997) indicated that a considerable number of studies identify elasticities of substitution between skilled labour and capital as less than 1.2 and some even find such elasticity as close as 0. In their study, Krusell et al. (1997) chose an elasticity of substitution between unskilled labour and capital equipment (not capital) of 1.5, which implies, ρ equals 0.33. By symmetry, the elasticity of substitution between skilled labour and unskilled labour was also 1.5. They chose elasticity of substitution between skilled labour and capital of 0.6, giving ν equal to -0.67. Drawing on these studies and especially on the work of Fallon et al. (1975), a value of $\rho = 0.33$ and $\nu = 0.17$ have been chosen for the calibrations done in this chapter. Accordingly, from the definition of elasticities of substitution given above, the direct elasticity of substitution between skilled and unskilled labour; and between capital and unskilled labour has been chosen as 1.49. The elasticity of substitution between capital and skilled labour has been equal to 1.20.

A whole set of different values of substitution parameters have also been used to perform a sensitivity analysis and these values have been chosen arbitrarily. The arbitrarily chosen variables mostly violated either both or at least one assumption made in the model discussed above. The graphical comparisons between observed and calibrated skilled-unskilled wage ratios have been presented in the results section of the chapter.

The value of the Hicks-neutral technology coefficient, A_i, has been calculated by solving the production function given in the equation (3.6.1), after substituting the above mentioned values of the parameters and variables. The Hicks neutral technological efficiency can be given by

$$A_i = Y_i\left[(\delta_Z Z_i)^{\rho} + (\delta_L L_i)^{\rho}\right]^{-1/\rho} \tag{3.12}$$

To solve for the Hicks neutral technological efficiency the factor biased technological efficiency parameters have been normalised to one, that is, $\tau_K = \tau_L = \tau_H = 1$.

To find the values of technological efficiency parameters of different factors used in the production process, the value of Z has been calculated by substituting the real values of Y, K, and H in the equation (3.6.1). This gives

$$Z_i = \frac{((Y/A)^{\rho} - (\delta_L L)^{\rho})^{1/\rho}}{(\delta_Z)} \tag{3.13}$$

Then, substituting the values of Z, K, and H in equation (3.6.1), the technological efficiencies for skilled labour and capital have been solved.

Again, the factor biased technological efficiencies for each factor have been solved using the equation (3.6.1), as follows

$$\tau_{Hi} = \frac{(Z_i^{\nu} - (\delta_K K_i)^{\nu})^{1/\nu}}{\delta_H H_i} \tag{3.14.1}$$

$$\tau_{Ki} = \frac{(Z_i^{\nu} - (\delta_H H_i)^{\nu})^{1/\nu}}{\delta_K K_i} \tag{3.14.2}$$

and

$$\tau_{Li} = \frac{((Y_i / A)^{\rho} - (\delta_Z Z_i)^{\rho})^{1/\rho}}{\delta_L L_i} \tag{3.14.3}$$

where, i denotes the time period, i = 1,2, …., n. A is the initial level of Hicks neutral technology defined in the equation (3.12).

The values of the technical efficiency parameters τ_K, τ_H, and τ_L have been calculated by normalising $\tau_j = 1$, where, j denotes the factors for which the efficiency has not been calculated, and solving for the technical efficiency of the other factor. By normalising the two efficiency parameters of capital and skilled labour to one, i.e., $\tau_K = \tau_H = 1$, the technical efficiency of labour, τ_L, has been calculated using the equation (3.14.3). Similarly, the efficiency parameter of the skilled labour has been calculated by normalising the efficiency parameters of capital and labour, i.e., $\tau_K = \tau_L = 1$ and using the equation (3.14.1). Also, by normalising $\tau_H = \tau_L = 1$, the efficiency of capital has been calculated using the equation (3.14.2). That is, in the process of calculating different types of efficiency, the effect of only one type of technological change has been investigated at a time, holding the rest of the technological efficiencies constant.

Defining all the parameters, the next step is to get the values of Hicks neutral technological change, A_i, for each period. Keeping A constant at its initial level, the factor biased technical efficiency (τ) has been calculated for each factor, taking only one at a time, for the entire range of the concerned period. After getting the values of the technology and efficiency parameters, the returns to different factor inputs in the model, defined by the equations (3.7.1), (3.7.2) and (3.7.3), have been calculated. In the process of calculations performed as described above, the observed values of income (GDP), physical-capital, skilled workers and unskilled workers for the years 1975 to 1995-96, have been used.

With different factor-biased technological change, the proximity between the actual and calculated skilled-unskilled wage ratios have been compared and analysed in the results section. In doing this, alternative assumptions have been made on the degree of elasticity of substitution and on the nature of bias in technological change.

3.5 Results

Figure 3.4 and Table 3.2 present the main results of the experiment. According to the model used in this chapter, if the technological change has been unskilled-labour augmenting then the ratio of skilled-unskilled wage in the economy would tend to close along the time path given the condition that the substitution among the unskilled and skilled workers has been easy. If the technological change has been skilled labour-augmenting then the effect on the skilled-unskilled wages would be the reverse. Given the assumption of capital-skill complementarity or $\rho > \nu > 0$, the skilled-unskilled wage differential would tend to widen as the capital stock goes up. The effect of capital-augmenting technological change would be similar to skilled labour augmenting technological change, but the magnitude could be different.

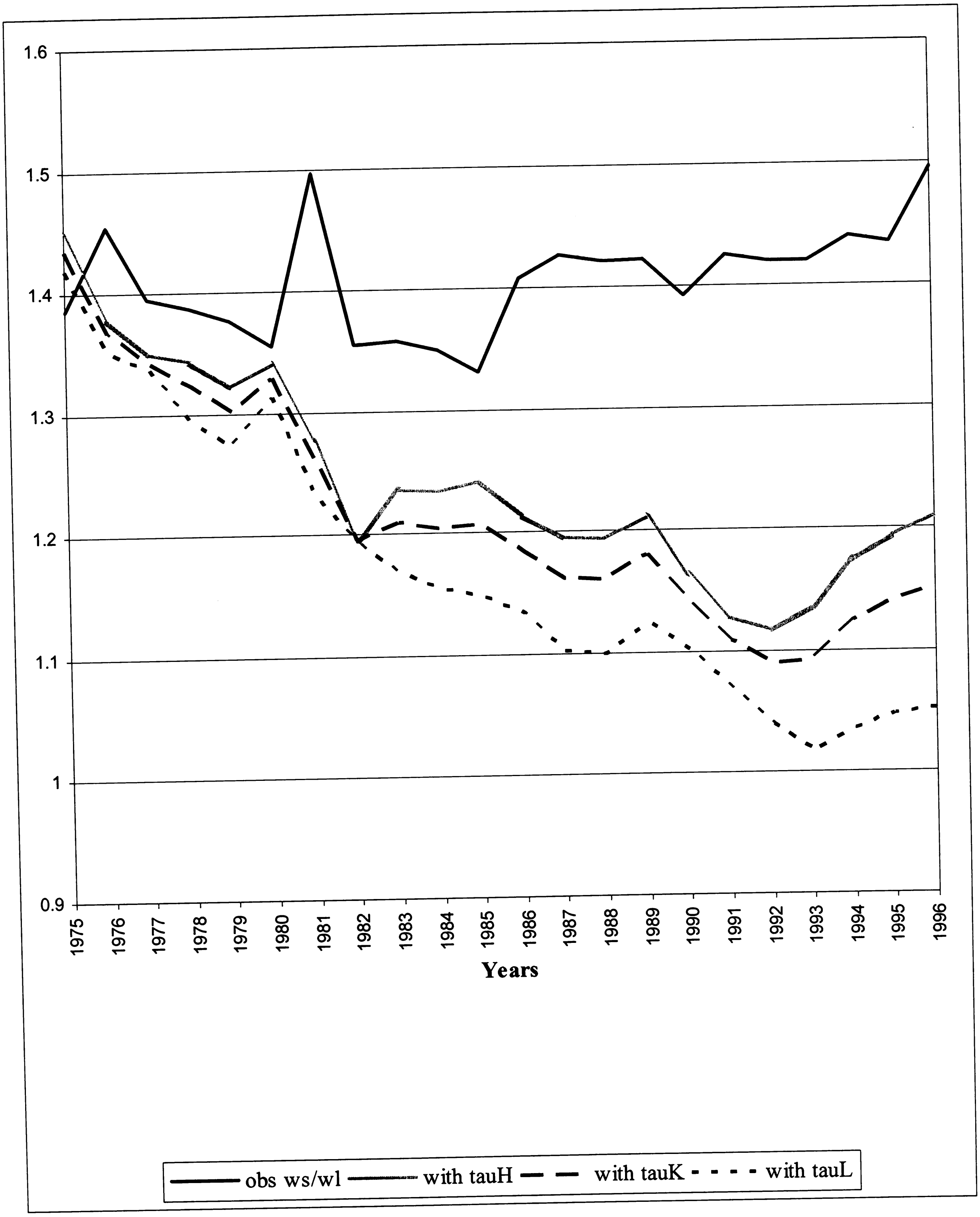
The wage differentials, using all the observed values in Australia from 1974 to 1996 have been calculated and graphically presented in Figure 3.4 and also tabulated in Table 3.2. If the technological change has been completely unskilled-labour augmenting then this calculated wage gap would be narrower over time. From equation (3.9.2) and (3.9.3) it has been observed that given the condition $\rho > \nu > 0$, the skilled labour augmenting or physical capital augmenting technological change would widen the skilled unskilled wage gap. The results, based on the observed values and chosen parameters, support the theory to some extent when the elasticities of substitution have been taken from the findings of the literature and the assumptions of capital-skill complementarity and ease of substitutability between capital (physical and human) and unskilled workers hold.

The calculated skilled-labour augmenting, unskilled-labour augmenting and capital augmenting technological change with same values of substitution parameters in each of the three cases and their individual effects on the skilled-unskilled wage ratio have been compared with the observed skilled-unskilled wage ratio. These results have been presented in Figure 3.4.

Figure 3.4 presents the observed skilled-unskilled wage ratio along with three different calibrated skilled-unskilled wage ratios when ρ equals 0.33 and ν equals 0.17. The elasticity of substitution among the skilled and unskilled workers and among capital and unskilled workers are both 1.49 and the elasticity of substitution between skilled workers and capital is 1.20. With these values of elasticities of substitution the skill-biased technological change has caused the skilled-unskilled wage ratio to be the closest to the observed skilled-unskilled wage ratio. The capital-biased technological change has also caused the skilled-unskilled wage ratio to be similar to what can be seen with skill-biased technological change. The only difference between these two biased technological changes can be described by their distance from the observed wage ratio.

The widening of the wage gap has been similar to the widening of wage gap by skill-biased technological change. Lastly, when the technological change has been unskilled-labour biased the skilled-unskilled wage ratio has gone further away from the observed wage ratio while compared to the other two factor-biased technological changes. One important point to note from these results is that while the difference to the actual time path of the wage ratio is least with the human capital augmenting technological change – the three are more similar to each other than to the actual series. The findings suggest that assuming capital-skill complementarity and keeping the elasticities within the range of those found in the literature, it has not been the unskilled-labour augmenting technological change that prevailed in Australia over the period 1975 to 1996. The model generated wage ratio with skill-biased technological change has caused the calibrated skilled-unskilled wage ratio to be the closest to the observed wage ratio among the three different factor-biased technological changes. Thus, it has been found that the benchmark model with skilled-labour augmenting technological change, calculated with all the observed variables, has been the closest to the historical variations in the wage differential over the period. Many economists (e.g., Bound and Johnson, 1992) defined this type of technological change as skill-biased technological change since such technological change shifts the demand for skilled labour helping the skill premium to increase even in the face of substantial increase in relative supply of skilled labour. But is should be noted that the factor-biased technological change (any one of them) could not explain most of the widening of the skilled and unskilled wages in Australia for the above mentioned time period.

Figure 3.4: Calibrated and Observed Wage Ratios with Parameter Values: $\rho = 0.33$, $\nu = 0.17$



Source: Author's calculations with $\sigma_{LK} = \sigma_{LH} = 1.49$ and $\sigma_{KH} = 1.20$.

The Table 3.2 is representing the results depicted in Figure 3.4.

Table: 3.2 Wage Ratios (Observed and with Different Factor-Biased Technological Change)

Year	W_H/W_L (Observed)	W_H/W_L (Calibrated with tau_H)	W_H/W_L (Calibrated with tau_K)	W_H/W_L (Calibrated with tau_L)
1975	1.39	1.45	1.43	1.42
1976	1.45	1.38	1.37	1.35
1977	1.40	1.35	1.34	1.34
1978	1.39	1.34	1.32	1.29
1979	1.38	1.32	1.30	1.27
1980	1.36	1.34	1.33	1.31
1981	1.50	1.28	1.26	1.23
1982	1.36	1.19	1.19	1.19
1983	1.36	1.24	1.21	1.17
1984	1.35	1.23	1.20	1.15
1985	1.33	1.24	1.21	1.15
1986	1.41	1.21	1.18	1.13
1987	1.43	1.19	1.16	1.10
1988	1.42	1.19	1.16	1.10
1989	1.42	1.21	1.18	1.12
1990	1.39	1.16	1.14	1.10
1991	1.43	1.13	1.11	1.07
1992	1.42	1.12	1.09	1.04
1993	1.42	1.13	1.09	1.02
1994	1.44	1.17	1.12	1.04
1995	1.43	1.19	1.14	1.05
1996	1.50	1.21	1.15	1.05

Sensitivity Analysis

The discussion on results would not be complete in this type of calibration based analysis if a sensitivity analysis has not been performed. Hence, with numerous different values of substitution parameters calibrations have been done and presented in Figures 3.5 to 3.18. The values that have been chosen for the parameters violated either or both the assumptions of the model presented above. Hence, the figures from 3.5 to 3.18 mainly present the wage ratios with skilled, capital and unskilled-labour augmenting technological change when capital and skill have not been complementarity to each other and the easy substitution among skilled and unskilled workers has not been possible.

The sensitivity analysis will help to understand the specific role of capital-skill complementarity assumption and hence, the nature of factor-biased technological change prevailing in Australia. Table 3.2 presents the different values of the parameters and the corresponding values of the elasticities of substitution between skilled & unskilled labour, unskilled labour and capital and between capital and skilled labour that have been used in the analysis. Sometimes the chosen values of the parameters violated the assumption of capital-skill complementarity. In some cases, the substitution elasticities among the skilled and unskilled and hence among capital and unskilled workers are very low. For the calibration the shares of different factors of production have been chosen according to the average shares of the factors prevailing in Australia over the period 1975 to 1996, as described in section 3.4.

Table 3.3 Sensitivity Analysis with Different Values of ρ and ν (Shares of Labour = 0.4, Capital = 0.4 and Human Capital = 0.2)

ρ	ν	σ_{LK}, σ_{LH}	σ_{HK}
0.04	-0.72	1.04	0.58
0.46	-0.81	1.85	0.55
-0.27	0.06	0.78	1.06
0.31	-0.24	1.45	0.76
-0.19	-0.85	0.84	0.54
-0.08	-0.19	0.93	0.84
0.398	-0.35	1.66	0.74
0.14	-0.10	1.16	0.91
-0.26	-1.50	0.63	0.40
0.10	-0.18	1.11	0.85
-0.11	-3.0	0.90	0.25
-0.124	-0.52	0.89	0.66
0.029	0.06	1.03	1.06
-0.45	-3.54	0.69	0.22
-0.59	-3.35	0.63	0.23

Figure 3.5 to 3.18 below present the actual skilled-unskilled wage ratio and the calibrated wage ratios with three different types of technological change for the period 1974 to 1996. From the figures it can be seen that with these arbitrarily chosen values of parameters and hence, the elasticities of substitution, the calibrated wage ratios could not maintain the predictions of the model. In most of these figures, it has been found that the calibrated skilled-unskilled wage ratio has narrowed down with skill-biased technological change but with capital-biased technological change the wage gap of skilled and unskilled workers has increased. The skilled-unskilled wage ratio with unskilled worker augmenting technological change has also increased and the increase has been at least more than the rise in the calibrated wage ratio with skill-biased technological change. The main reason behind these results in the sensitivity analysis has been the chosen values of elasticities of substitution. The chosen values of elasticities of substitution do not follow estimated and reported elasticities of substitution in different studies mentioned earlier. These chosen values also do not hold the assumptions of capital-skill complementarity and ease of substitution among the skilled and unskilled workers.

When the elasticities of substitution have been close to one (that is the production function is Cobb-Douglas type) then the wage ratios with different technological change have been very close to each other (as in Figure 3.17). When the parameter values and hence, the elasticities of substitution remained within the range of what have been reported in the literature, the calibrated skilled-unskilled wage ratio with different technological change have been of the expected nature as illustrated in Figure 3.4.

Figure 3.5: Parameter values, ρ=.04, ν=-.72

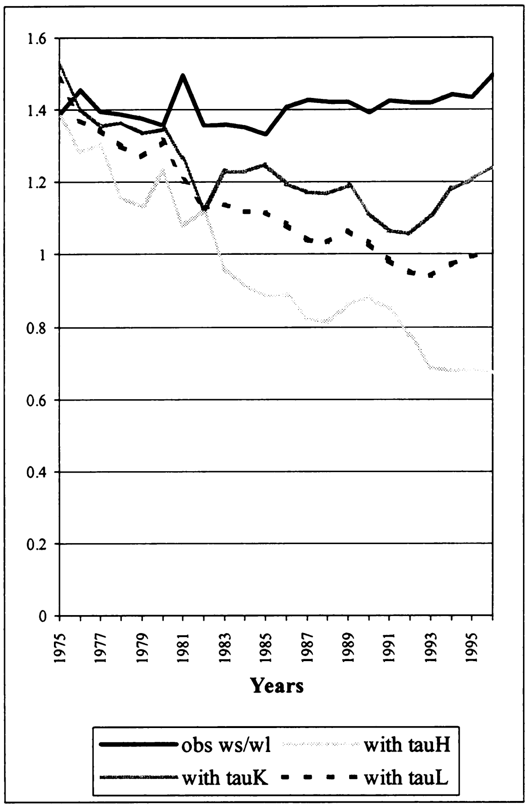


Figure 3.6: Parameter values, ρ=.46, ν=-.81

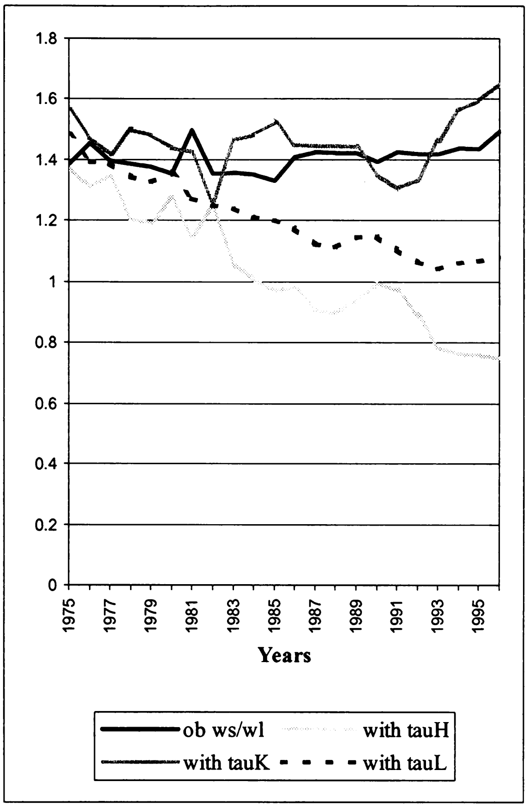


Figure 3.7: Parameter values, ρ=-.27, ν=.06

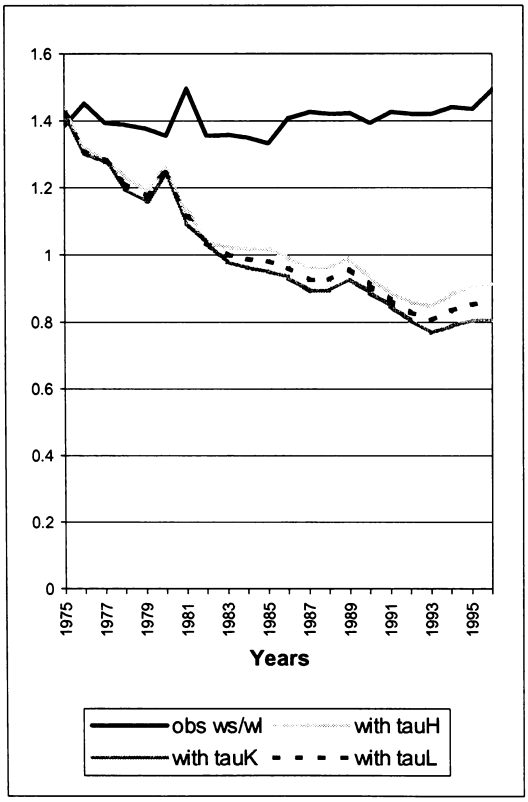


Figure 3.8: Parameter values, ρ=.31, ν=-.24

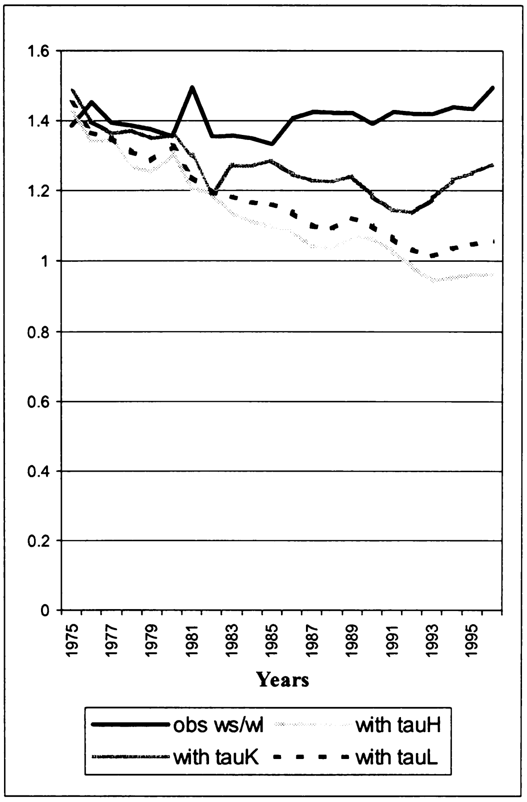


Figure 3.9: Parameter Values, ρ=-.19, ν=-.85

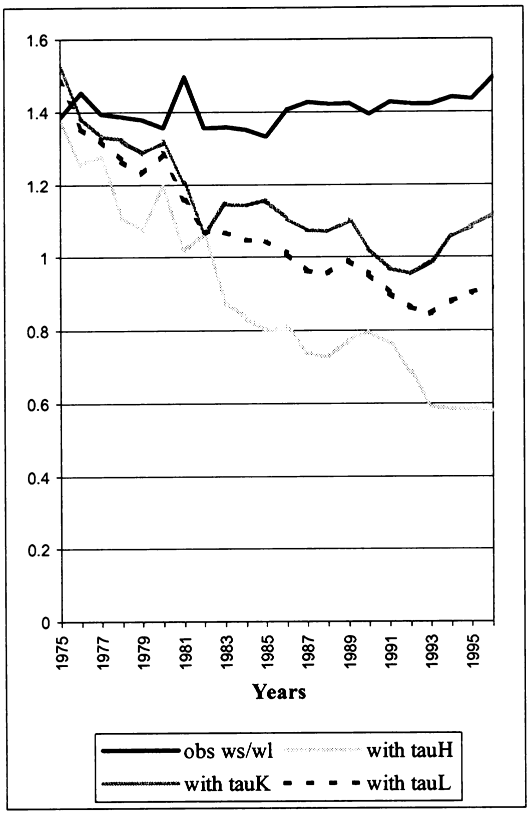


Figure 3.10: Parameter Values, ρ=-.08, ν=-.19

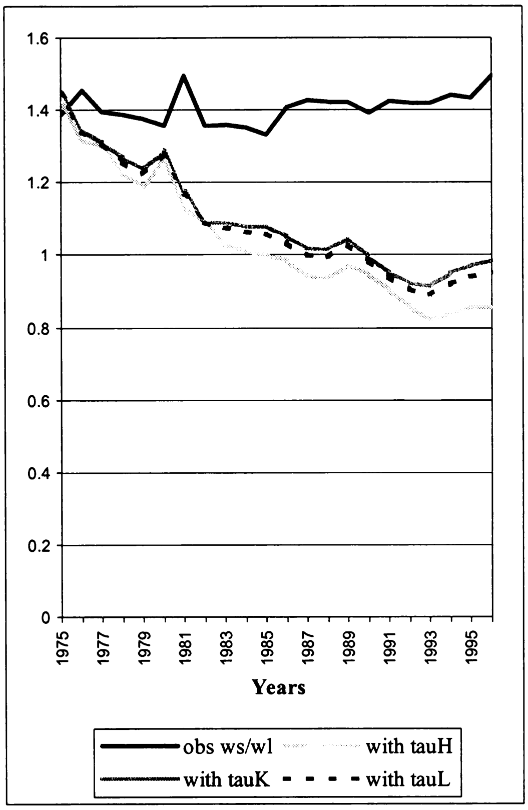


Figure 3.11: Parameter Values, ρ= .398, ν=-.35

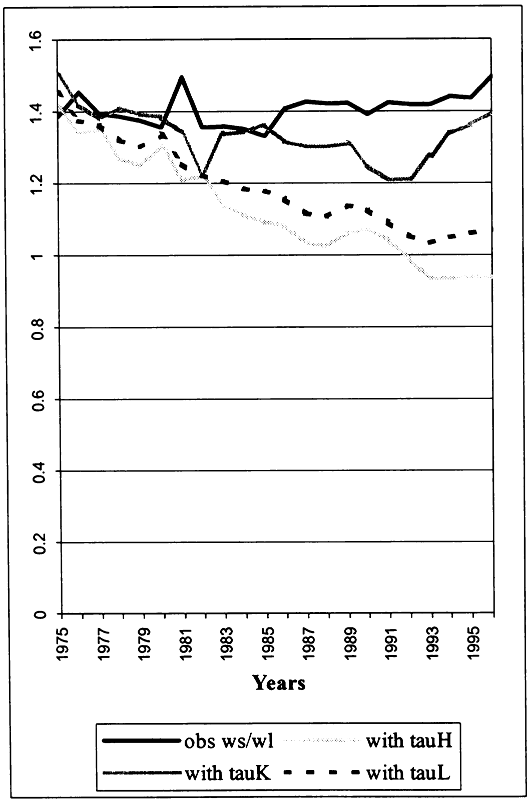


Figure 3.12: Parameter Values, ρ= .14, ν=-.10

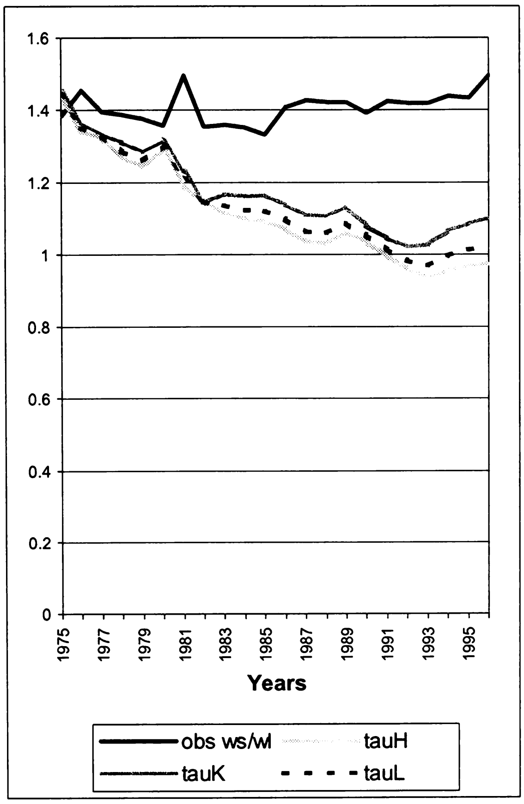


Figure 3.13: Parameter Values, ρ=-.26, ν=-1.50

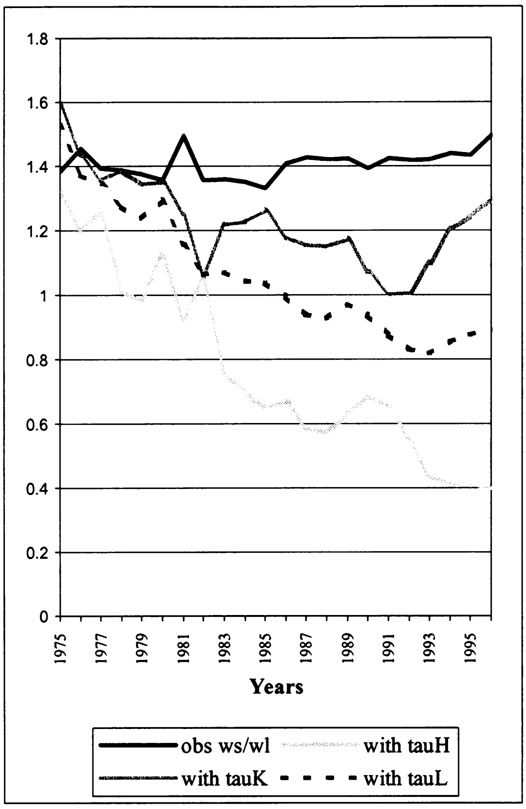


Figure 3.14: Parameter Values, ρ=.10, ν=-.18

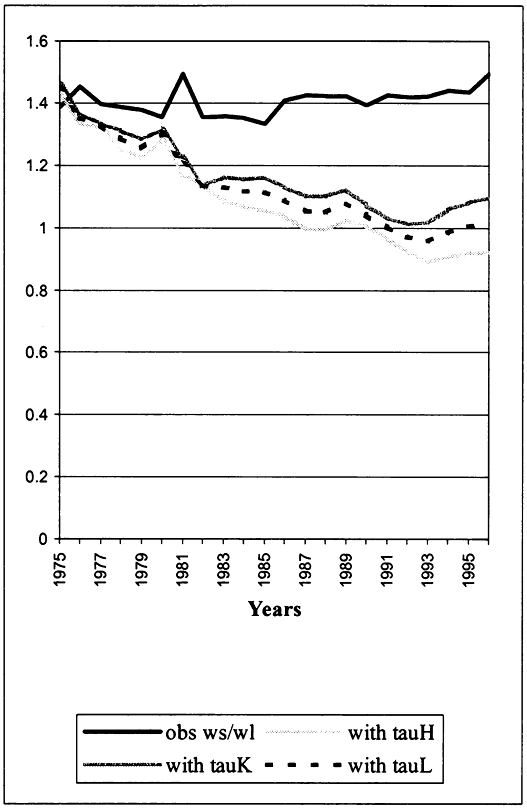


Figure 3.15: Parameter Values, ρ= -.11, ν=-3.0

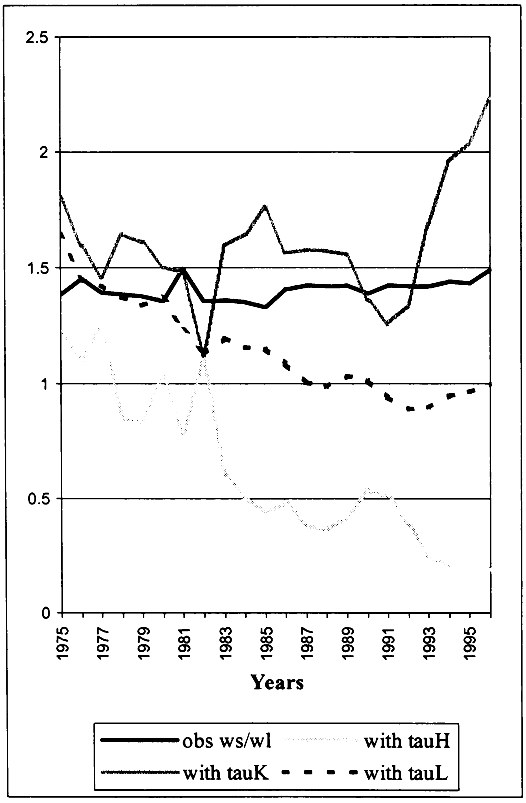


Figure 3.16: Parameter Values, ρ= -.124, ν=-.52

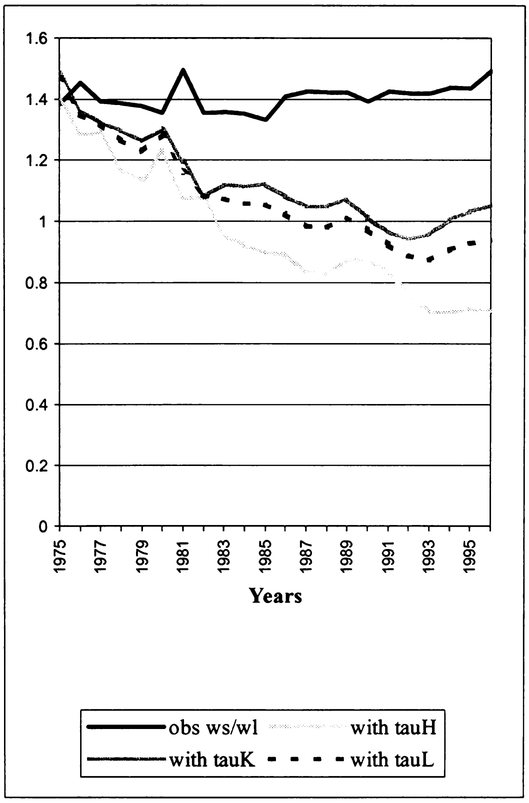


Figure 3.17: Parameter Values, ρ= .029, ν= .06

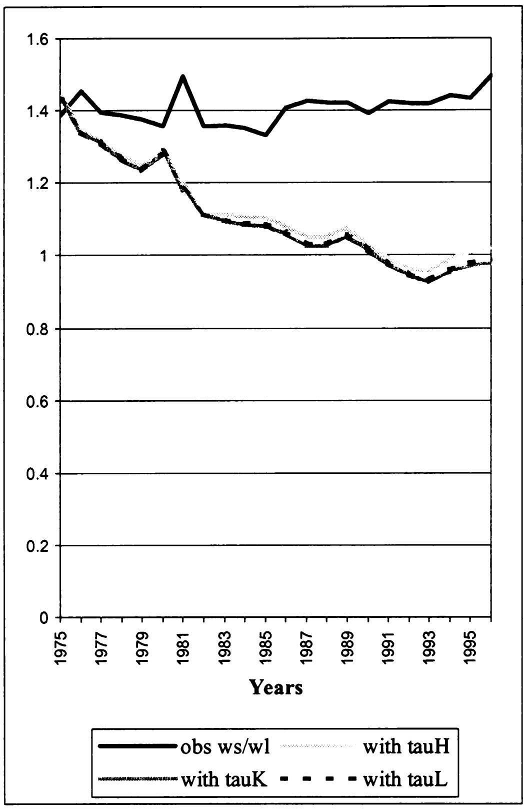
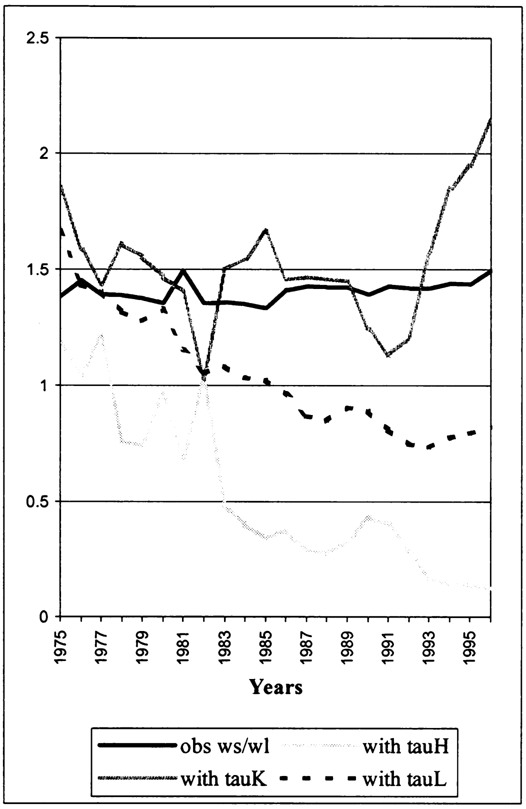


Figure 3.18: Parameter Values, ρ= -.45, ν= -3.54



The sensitivity analysis which calculated the skilled-unskilled wage ratios with different values of parameters that violate the assumptions of the model have produced the above results. When the technological change has only been unskilled-biased, the gap between the skilled-unskilled wages has risen more than the case where technological change has been only skill-biased. According to the theory in case of unskilled-biased technological change there would be a shift in relative demand for unskilled workers in the economy. This stands in sharp contrast with what can be seen from the observed skilled-unskilled employment ratio for the period of 1975 to 1996 in Australia. This is presented in Figure 3.2. Hence, it can be concluded from the results of the study that capital-skill complementarity has been a component in Australian production process in macro level over the period of 1975 to 1996. Fallon and Layard (1975) and Krusell et al. (2000) found evidence of capital-skill complementarity in U.S. Krusell et al. (2000) interpreted the capital-skill complementarity as skill-biased technological change. Hence, the results of this chapter support the view that the skill-biased technological change is a major component in accounting for the rising wage inequality (but not the only one explanation) among the skilled and unskilled workers in Australia.

3.6 Conclusions

This chapter has presented an overview of Australia's capital growth, skilled-unskilled employment ratio and skilled-unskilled wage ratio for the period 1975 to 1996 adopting a macroeconomic analytical perspective. The study finds that with the assumptions of capital-skill complementarity and easy substitutability among skilled and unskilled workers and capital and unskilled workers, skill-biased technological change could explain the movements in skilled-unskilled wage inequality better than the other two-factor biased technological changes at macroeconomic level. But the results suggest that the factor-biased technological changes are not the sole cause of increasing skilled-unskilled wage inequality. According to the results, if the above-mentioned assumptions have been fulfilled then the calibrated skilled-unskilled wage ratio with skill-biased technological change becomes the *closest* to the observed skilled-unskilled wage ratio compared to the calibrated wage ratios with other two factor biased technological changes. . But much of the observed widening of skilled-unskilled wage ratio remains unexplained. The results have been depicted in Figure 3.4. The sensitivity analysis presented in Figures 3.5 to 3.18 made the findings stronger by revealing the fact that capital-skill complementarity has been a major component in Australian production process over the period 1974 to 1996 and the capital-skill complementarity implies skill-biased technological change (Krusell et al., 2000).

One major weakness of this study is that with any chosen values of substitution parameters and hence substitution elasticities, it is unlikely that the calibrated skilled-unskilled wage ratio would be exactly the same as the observed one. In the sensitivity analyses it has also been observed that when the ease of substitutability among the skilled and unskilled workers has been relaxed the results of calculations changed. Hence, the ease of substitutability assumption is another major limitation of the method used in this study. Moreover, the impacts of technological change on wages have been varied only one at a time, keeping the others equal to one, which may not be always the case in reality. It should also be noted that technological change may not be the sole cause of rising wage inequality among the skilled and unskilled wages. For a developed economy, in particular, increased trade with developing countries could also prove to be another pronounced factor that could cause widening wage gap among the skilled and unskilled workers in the developed economy. In chapter four, a comprehensive research is carried out on this increased trade issue.

Chapter Four

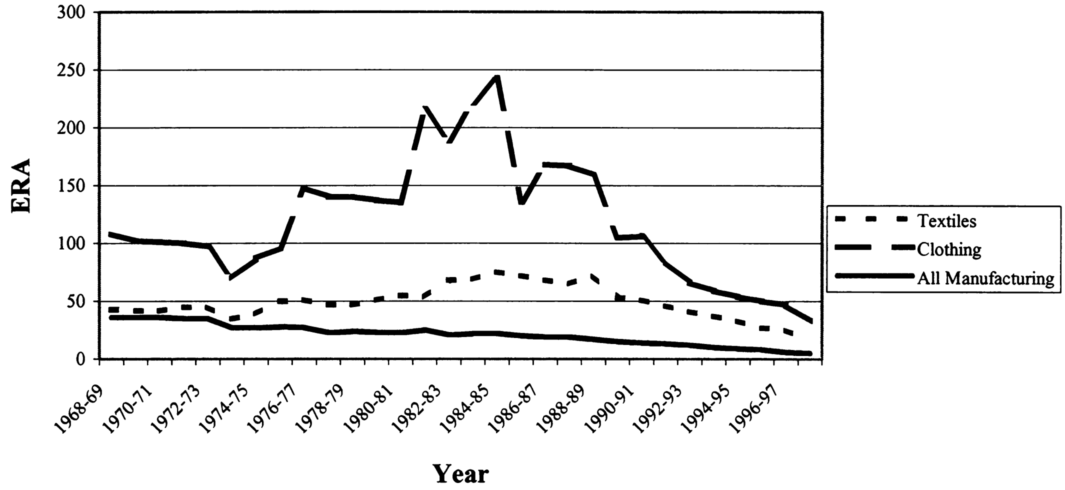
International Trade Effects in Australian Manufacturing: An Empirical Analysis

4.1 Introduction

Over the last two decades or so, Australian economy has become more integrated with the rest of the world. The degree of protection from import competition given to the domestic producers fell significantly over this period. As a result of the reduced protection, Australia's manufacturing imports from both the developed and developing countries started to increase. From 1982 to 1999, share of manufacturing imports in manufacturing value-added rose from 19.5 percent to 68.1 percent. Over this period, share of imports from developing countries in total imports of Australia rose by 11.95 percent. Since manufacturing sector is mainly unskilled labour-intensive, Australia's imports of manufactured products from the developing countries have grown significantly over past few decades. In view of Stolper-Samuelson (1941) and factor price equalisation theory of trade, it is expected that unskilled workers in Australia would be impoverished or unemployed due to the increased trade with developing countries. This in turn, suggests that the increased trade with developing countries would result in rising wage inequality among the skilled and unskilled workers.

Figure 4.1 presents the trends in protection accorded to the domestic producers in Australia. The figure shows the Effective Rates of Assistance (ERA) provided to the entire manufacturing sector as well as to textiles and clothing industries from 1968-69 to 2000-01. The ERA is measured as the difference between value-added per unit of an activity measured with and without assistance (in the form of border tariff or non-border interventions). In other words, ERA is expressed as a percentage of value-added per unit, measured in unassisted price. The effective rate measures net assistance, by taking into account of the costs and benefits of government interventions on factor inputs, which is the direct assistance to value-adding factors as well as the output assistance (Productivity Commission, 2000 p.10). From 1968-69 to 1998-99 the ERA provided to manufacturing industry in Australia fell significantly from 34.9 percent to 5.2 percent (Figure 4.1). While ERA provided to the overall manufacturing sector declined, some industries, such as, textiles and clothing had been given much higher rates of protections.

Figure 4.1 Effective Rates of Assistance to Textiles, Clothing and All Manufacturing, Percent



Source: Productivity Commission (2000)

As the table shows, the ERA accorded to textiles and clothing increased from mid 1970's to early 1980's (specifically, until 1984-85) and then began to decline. The ERA index for clothing industry rose to 240 percent in 1984-85 and the index for textiles went above 70 percent by at the end of 1980's. Figure 4.1 also shows that the rate of assistance provided to these industries has sharply declined since 1989-90 and by the end of year 2001, the rate of assistance provided to textiles and clothing industries declined to 33 percent and 17 percent, respectively. Despite such high levels of assistance received by the textiles and clothing industries, the manufacturing sector as a whole has received no more than 5 percent of ERA in the recent years.[1]

A closer look at the trend of Australia's growing international trade and its growing share to manufacturing value added and GDP would clearly reveal why there have been increasing concerns about Australia's growing trade with developing countries. Over the past decade, there has been a trend of rising net manufacturing imports (total and from the developing countries) relative to both manufacturing value-added and total

[1] An overview of the trend in openness (measured in terms of real exports and imports) of Australian economy over the past two decades has been presented in Appendix A4.I.

GDP of Australia. This has been accompanied by falling proportion of manufacturing employment to total employment. For example, proportion of manufacturing employment to total employment in Australia has declined from 9.5 percent in 1982-83 to 7.3 percent in 1998-99. Table 4.1 reports share of Australian manufacturing imports to manufacturing value-added and total GDP for few selected years. The share of domestic manufacturing output as a proportion of total GDP and share of manufacturing employment to total employment have also been presented in the table. These two shares have declined over the period 1982 to 1999. At the same time, as Table 4.1 shows, the share of manufacturing imports as a percent of manufacturing value-added, and the share of net manufacturing imports (imports minus exports) as a percent of manufacturing value-added has been rising. Some economists, for example, Paul Krugman, Robert Lawrence, Matthew Slaughter, Jagdish Bhagwati, Vivek Dehejia, argue that the trend of rising share of manufacturing imports in the developed countries is mainly attributable to rapid productivity growth (stemming from technological change) in manufacturing, which causes the relative price of manufacturing products to fall compared to the non-manufacturing products.

Table 4.1: Ratio of Production, Employment and Trade in Manufacturing, 1982-1999

Year	Manufacturing GDP to Total GDP	Manufacturing Employment to Total Employment	Manufacturing Imports to Manufacturing Value Added[a]	Manufacturing Imports to total GDP	Manufacturing Net Imports to Manufacturing Value Added[b]	Manufacturing Net Imports to total GDP[b]
Column 1	Column2	Column3	Column4	Column5	Column6	Column7
1982-83	0.299	0.095	0.315	0.095	0.135	0.041
1986-87	0.219	0.091	0.537	0.117	0.277	0.061
1992-93	0.151	0.079	0.821	0.124	0.371	0.056
1996-97	0.135	0.078	0.992	0.133	0.414	0.056
1998-99	0.125	0.073	1.183	0.164	0.681	0.085

Source: Author's calculations using data from ABS Spreadsheet: Table 520611a, Table 5206015, Table 17 and Table 47 for GDP and Industry Value Added data, Table 9C and 9I for Total Labour Force and Industry Labour Force data and ABS Cat. No. 5422.0. Trade data have been collected from Department of Foreign Affairs and Trade (DFAT) publication on Trade data (2000). Data on 1982-83 manufacturing employment have been from UNIDO three-digit database.

a. Manufacturing Imports and Exports comprise of trade from all countries with SITC codes 0 (excluding Live Animals), 1, 5, 6, 7, and 8 of Merchandise Trade.
b. Net imports have been defined as Australian Imports minus Exports from all trading partners.

However, it is observed from Table 4.1 that share of manufactured imports to GDP has increased steadily from 1982-83 to 1998-99 with a strong growth recorded between 1982-83 and 1986-87. Column 4 of the table clearly reveals that the share of manufacturing imports in total manufacturing value added has also increased continuously from 1982-83 to 1998-99. As this column shows, manufacturing imports has been 32 percent of manufacturing value-added in 1982-83 and has grown to 82 percent by 1992-93. By the end of 1998-99, manufactured imports has grown to 118 percent of manufacturing value-added. Manufacturing net imports as percent of total GDP has been 4 percent in 1982-83, remains steady at 5.6 percent during the period 1992 to 1997 and then has increased to 9 percent by the year 1998-99 (Table 4.1). Manufacturing net imports as a percent of manufacturing value-added was only 14 percent in 1982-83 and has grown to 68 percent in 1998-99. In contrast, the manufacturing employment as a percent of total employment has been falling steadily during this period. The fall of the share of manufacturing employment has been the highest between 1986-87 and 1992-93 (Table 4.1).

Table 4.2 shows the growing import penetration (measured as the ratio of imports to value-added) in Australia from developing countries. The Table also shows the trend of Australia's manufacturing imports from developed, developing as well as from all countries, over the period 1982-83 to 1998-99. It is observed from Table 4.2 that in 1982-83, the share of manufacturing imports from developing countries to GDP was only 1.5 percent. By the end of 1998-99, the share has increased to 4 per cent. Table 4.2 also shows that from 1982-83 to 1998-99 shares of Australian manufacturing imports from both developing and developed countries to total GDP has increased by about 3 per cent. The share of manufacturing imports from developing countries to manufacturing value-added has increased from 5 percent to 18 percent over 1982-83 to 1992-93. In the subsequent years, the share has grown at a faster rate climbing up to 33 percent in 1998-99, which is more than eight times the proportion in 1982-83. Table 4.2 also shows that the shares of manufacturing imports from developing countries to GDP, has increased significantly over the period 1982-83 to 1998-99. This rise in trade with low-income countries and the rise in wage inequality among the skilled and unskilled workers have the same timing. However, the share of manufacturing imports from developed countries to GDP has also grown over the period 1982-83 to 1998-99. Note that the shares of imports to GDP from developed and developing countries have grown by about the same rate (of around 3 per cent) during the period 1982-83 to 1998-99. Share of manufacturing imports from developing countries to GDP was 7 percent in 1982-83 and has grown to 10 percent by 1998-99. Similarly, the share of manufacturing imports from these countries to manufacturing value-added has increased from 25 percent to 87 percent within this period (Table 4.2).

Table 4.2: Manufacturing Total Imports as a share of GDP and Manufacturing Value Added by Country Groups, 1982-83 to 1998-99

	Manufacturing Imports to GDP			Manufacturing Imports to Manufacturing value-added		
Year	All Countries	Developed Countries[a]	Developing Countries[b]	All Countries	Developed Countries[a]	Developing Countries[b]
1982-83	0.094	0.076	0.015	0.315	0.254	0.049
1986-87	0.117	0.091	0.021	0.537	0.415	0.094
1992-93	0.124	0.091	0.028	0.821	0.601	0.184
1996-97	0.133	0.091	0.034	0.991	0.675	0.254
1998-99	0.164	0.106	0.042	1.183	0.875	0.334

Source: Author's calculations using data from DFAT Trade Data and ABS Cat. No. 5422.0.
a. Developed countries consist of all the countries of European Union (EU) for 1982 to 1993 European Community and European Free Trade Association (EFTA))and U.S.A., Japan and New Zealand
b. Developing countries consist of the countries with low income defined by ABS.

In Table 4.3, the trends in Australian imports from few of its major trading partners of the developing world have been presented. This table also shows shares of manufacturing imports from developing and developed country groups to total manufacturing imports and their percent changes during the period concerned. As the table indicates, Australia's share of manufacturing imports from developing countries to total manufacturing imports has increased over the period 1982 to 1998. It also presents the fact that Australia's share of manufacturing imports from developed countries to total manufacturing imports has declined over the same period. Further, the share of manufacturing imports to total manufacturing imports from developing countries has increased from 16.3 to 28.2 percent between 1982 and 1998.

It is also found from Table 4.3 that in 1982-83, 11.4 percent of total manufacturing imports has come from five developing countries and this share has increased to 19.03 percent (out of a total 28.2 percent of imports from all the developing countries) by 1998-99. Increased trade with developing countries has been a result of trade liberalisation under the auspices of the General Agreement on Trade and Tariff (GATT) and now the World Trade Organisation (WTO). Liberalisation of the manufacturing sector in Australia and reduced cost of transport and communications have also significantly contributed to increasing trade of Australia with the developing countries.

Most of the increase in imports from the developing countries to Australia has been from a small group of East Asian countries as seen in Table 4.3. Over the period 1982-83 to 1998-99, while imports from China grew by 5.07 percent, imports from Korea grew by 2.67 percent. This trend of increasing share of imports from low-wage developing countries raises serious concern about the consequences of such trend on Australian manufacturing employment, specifically on unskilled workers.

Table 4.3: Australian Manufacturing Imports by Country Group, 1982-83 to 1998-99
Millions of Dollars (Australian), Percent

Country Groups	1982-83		1992-93		1998-99		Change, 1982-83 to 98-99	
	Dollar Value	Percent Share[a]	Dollar Value	Percent Share[a]	Dollar Value	Percent Share[a]	Dollar Value	Percent Share[a]
All Countries	16343	100	50545	100	87508	100	71165	0
Developed Countries	13679	83.7	38687	76.5	62787	71.8	49108	-11.95
Developing Countries	2664	16.3	11858	23.5	24721	28.2	22057	11.95
Top Five Developing Trading Partners of Australia								
China	257	1.57	2557	5.06	6105	6.98	5848	5.41
Taiwan	649	3.97	2212	4.38	2978	3.40	2329	-0.57
Korea	288	1.76	1695	3.35	3894	4.45	2199	2.69
Philippines	84	0.51	177	0.35	405	0.46	321	0.05
Indonesia	561	3.43	1305	2.58	3275	3.74	2714	0.31

Source: Author's Calculations using trade data from ABS Cat. No. 5422 and DFAT Trade Data.
a. Shares are Australian manufacturing imports from the country group or country divided by total manufacturing imports.

To date, there has been no consensus among economists as to the role of international trade in widening wage inequality between skilled and unskilled workers. Lawrence and Slaughter (1993), Krugman (1995, 1996) argued that competition from abroad played an insignificant part in rising wage inequality in the U.S. manufacturing. Borland and Foo (1996) provided similar arguments to explain labour market behaviour and wage patterns for Australian manufacturing over the period 1978 to 1987. They found that manufacturing industries, categorised according to two-digit Australian Standard Industrial Classification (ASIC) codes, those experienced the largest shift towards skilled workers had the smallest exposure to international trade during this period. Leamer (1994), Wood (1994, 1995) and Haskel and Slaughter (1999) concluded that increased international trade had substantial effects on the U.S. and U.K. labour markets. Sachs and Shatz (1994) also found evidence of international trade as the cause of widening skilled-unskilled wage gap in the U.S. Although they found that international trade is squeezing the wages of unskilled workers in the U.S., i.e., there have been some evidences of the existence of Stolper-Samuelson (S-S) effects, but the effect is not large enough to account for a significant widening of wage inequalities. Fahrer and Pease (1994), Gaston (1998) and Karunaratne (1999) found mixed evidences in Australian manufacturing. They concluded that although part of the rising wage inequality can be attributed to international trade and hence the S-S effect, internationalisation itself cannot explain most of the observed labour market movements in Australia.

Apart from examining evidence of S-S effects, factor content measurement of trade is another method of measuring the trade effects on labour market. Using counterfactual measurement of trade, Sachs and Shatz (1994) found that over the period 1978 to 1990, while trade with developed countries had almost no net effect on U.S. employment, trade with developing countries had reduced 5.7 percent of U.S. employment. Wood (1994) found similar effects of trade on U.S. manufacturing employment. In fact, Wood (1994) identified larger trade effects than those measured by Sachs and Shatz. Some researchers such as Fahrer and Pease (1994), and Murtough, Pearson and Wreford (1998) have done input-output analysis of Australian employment changes using shift share analysis and OECD (1992) technique, respectively. OECD input-output analysis technique uses labour-output ratios (labour-output ratios are held constant at their base year levels to calculate the effects of increased imports on reducing the labour demand) to calculate changes in the use of labour attributable to growth in a country's exports and imports. The net impact of trade on employment is the difference between changes in labour use due to exports and imports (Murtough et al., 1998)[2]. Fahrer et al., (1994) in their input-output analysis for Australia over the period of 1981/81 to 1991/92 found that like other industrialized countries, productivity improvements have far greater effects on manufacturing job losses than increased trade with low wage countries. The only industry where imports from low wage countries accounted for a substantial decrease in employment was Clothing and Footwear. They also found that low wage imports accounted for a large number of gross job losses in Textiles and Miscellaneous Manufacturing, but not after netting out the effect of domestic demand and exports

[2] For details of OECD (1992) technique of input-output analysis see Murtough et al., (1998, pp. 91-92).

(Fahrer et al., 1994, p. 203). Murtough et al., (1998) found similar results for Australia over the period of 1986-87 to 1993-94. They found that the net impact of trade was positive for export oriented Food, beverages and tobacco and Basic metal products industries. The largest negative net impacts of trade have been found in the import competing industries of Clothing and footwear and Motor vehicles and parts. All these trade effects are measured for employment as a whole. These studies did not differentiate the possible effects of trade on skilled and unskilled workers.

The concern that increased international trade with developing countries would hurt the workers, especially the unskilled workers of a developed country, raises the question as to what would be the basis of trade between a developed and developing country. If the trade between a developed and developing country were based on comparative advantage, then this would affect the labour market adversely in the developed countries, as predicted by Heckscher-Ohlin-Samuelson (HOS) models of international trade. According to the HOS theory of international trade when a developed country starts trading with a developing country based on comparative advantage, the unskilled workers of the developed country would face falling relative wages or rising unemployment if the wages are rigid and the labour market does not clear. On the other hand, the 'new trade theory' (Ethier, 1982; Krugman, 1984, 1986; Brander and Spencer, 1985) suggests that trade among developed countries are more of intra-industry in nature, i.e., a two-way trade within industry categories. The theory also suggests that trade between a developed and developing country would be of inter-industry type, based more on comparative advantages. If this were to be the case for Australia, then Australia's increased trade with developing countries would result in significant net job losses and would also result in significant shifts in wages among workers of different skill levels. This is an important issue, as this would show the power of internationalisation to affect labour market in Australian manufacturing industries. The limited evidence of trade effects on Australian labour market movements available to-date might have owed to the lack of efforts in distinguishing the inter-industry and intra-industry trade and in relating such features to Australian labour market.

Sachs and Shatz (1994) estimated the relationship between intra-industry trade index and relative wages of partner countries (with respect to U.S. wages) for manufacturing industry as a whole. They found that U.S.'s trade with low-wage countries causes significant net job losses in U.S. manufacturing industry. In their study, however, other factors that could be said to affect the intra-industry trade index and hence, the trade pattern with developed and developing countries, were not controlled for.

There have been few studies that measure the overall intra-industry trade index of Australia in different manufacturing sectors. For example, Greenway and Milner (1999) tested industry-specific hypothesis of the determinants of intra-industry trade in the context of trade between U.K. and Australia. They separated intra-industry trade into horizontally differentiated and vertically differentiated products and concluded that the latter is the dominant type of intra-industry trade between Australia and UK. In another recent study, Havrila and Gunawardana (2003) calculated Grubel-Lloyd index of intra-industry trade for seven categories of textiles and two categories of clothing for Australia over the period from 1965 to 1996. In their study they found that there has been a rising trend in intra-industry trade in some of these categories of textiles and clothing products for Australia.

The major contribution of this chapter to the existing literature could emanate from the fact that, this chapter investigates the trade effects on labour market based on the nature of the trade involving various countries and sectors. Such an analysis would be worth doing since while examining international trade effects on labour market, most of the studies overlook the different types of trade involving various countries and sectors (or in other words, most of the studies focus only on the inter-industry and not intra-industry trade effects). This chapter addresses the question with regard to the type of trade Australia has with its developed (or high wage) and developing (or low-wage) trading partner countries. It also examines whether increased trade with developing countries (low wage countries) would cause significant net job losses and would cause significant shifts in wage distribution among workers of different skill levels. To examine these issues, intra-industry trade index of Australia with its major trading partners, in eight different carefully chosen manufacturing industries, have been measured. The intra-industry trade index serves as the indicator of Australian trade pattern in those specific industries. In the next phase, the relationship between the trade pattern (revealed by intra-industry trade index) and industry specific relative wages of the partner country to the Australian wages (indicating the relative income status of the trading partner) has been estimated for each industry, using a cross-section data for the year 1995 of Australia's major trading partners (52 countries). If the relationship between intra-industry trade indexes and relative wages of trading partners is found to be positive then Australia's trade with high wage countries is intra-industry and trade with low wage countries is more of inter-industry type. When the trade pattern is more of intra-industry type, the trade effects on wage distribution will be small and there will be substantial extra gains from international trade. These extra gains would be over and above the gains from inter-industry trade or in other words, trade based on comparative advantage. On the other hand, if the trade pattern were more of inter-industry type (which is expected to be the case when Australia trades with low wage countries, due to the lack of similarities in their relative factor supplies) then the effects on the labour market would be found in terms of net job losses and shifts in wage distribution would be according to what is predicted by the S-S or factor price equalisation theory. In this chapter, to remedy the weaknesses of the study by Sachs and Shatz (1994) mentioned above, the relationship between intra-industry trade index and relative wages of the trading partners have been estimated after controlling for few more variables that are the standard explanatory variables used in the gravity models, namely, size of economies and distance of the trading partners.[3] Exchange rates between Australian dollars with currencies of its trading partners have also been used as an explanatory variable. Another scale variable for openness, measured as ratio of trade with each partner country to Australian GDP, has been included in the regression in view of the fact that GL index does not account for the volume of trade. Using a counterfactual trade method, the scope of this study has been extended further by measuring factor content of trade for different Australian manufacturing sectors for the period 1986 to 1996. This chapter looks into the trade effect in two-digit manufacturing sectors, by disaggregating the total effects into two components, for the skilled and unskilled employment in Australia. The chapter also compares these counterfactual changes with actual changes in employment over the period.

[3] Gravity models were first proposed and applied by Tinbergen (1962) and Pöyhönen (1963). They asserted that the volume of trade between two trading partners is an increasing function of their national incomes and a decreasing function of the distance between them. Gravity models have been criticised for the lack of any theoretical basis but widely used due to its empirical success. The theoretical foundations were later developed by Anderson (1979) and Bergstrand (1985). Deardorff (1998) demonstrated that gravity models can be derived from Ricardian and Heckscher-Ohlin frameworks (Wall, 2000).

The possible presence of S-S effects in some specific manufacturing industries in Australia has also been examined in this chapter.

It has been difficult to find a single comprehensive source of information that included all the required data used in this study. The main sources of data used in this chapter include published and unpublished databases of Australian Bureau of Statistics (ABS), United Nations Industrial Development Organisation (UNIDO) database, World Bank DX economic databank (World Bank World Tables) and Australian Department of Foreign Affairs and Trade (DFAT) publications.

The rest of the chapter is planned as follows. Section 4.2 includes the discussion of some theories of international trade that are relevant for this study. Section 4.3 presents a comprehensive data description and details the specifications of different models used. Section 4.4 presents the results and analyses the S-S effects as well as factor content measurement of trade. The section also estimates the pattern of Australia's trade with its major trading partners. Section 4.5 summarises and concludes.

The main findings of this study indicate that there have been some evidences of the effects of increased international trade on the wages and employment in the highly unskilled-labour intensive industries in Australia. For example, S-S effects are found in Australian clothing & footwear industry since 1989. From this year the protection given to clothing & footwear has been reduced drastically. The results of factor content of trade measurements show that Australia's increased trade cannot explain most of the changes in the skilled labour demands but could explain some of the changes in unskilled labour demand over the period 1986 to 1996. The results from estimated effects of the industry specific relative wages of partner countries (revealing income status of the trading partners) on Australian trade pattern for the year 1995 also provide little evidence that trade with developing countries cause significant distortions in Australian labour market. The findings of this study indicate that while international trade can have some limited effects, it is unable to explain most of the labour market movements in the manufacturing industries in Australia.

4.2 The Theoretical Framework of International Trade

Heckscher-Ohlin and Stolper-Samuelson theory of International Trade

The general Heckscher-Ohlin (H-O) theory of trade, in a two-country, two-factor, and two-good model, states that the differences in factor endowments in the trading countries determine the trade. The assumptions of H-O theory are: (1) there are no transportation or other costs of trade; (2) perfect competition prevails in both commodity and factor markets (factors of production are allocated optimally); (3) production functions are homogeneous of degree one; (4) two goods have different factor intensities in their production; (5) the production functions are different for two industries but are same in two countries (i.e., technology travels freely among countries). The theory states that the country that is relatively abundant in any factor will produce the good that uses the abundant factor relatively intensively and export the product. Let us assume that there are two countries, one developed and one developing, and that both the countries use two factors of production, skilled and unskilled labour. Let, each country produce two products, skill intensive pharmaceuticals and unskilled labour intensive footwear. Let us also assume that the developing country is abundant in unskilled labour and the developed country is abundant in skilled labour force. Given this scenario, according to the H-O theory, it would be relatively cheap for the developing country to produce footwear and for the developed country to produce pharmaceutical products. From there it follows that with free trade, the developing country, which is abundant in unskilled labour, would export the unskilled labour-intensive good footwear and the developed country, which is abundant in skilled labour, will export pharmaceutical goods, the skilled labour-intensive products.

The Stolper-Samuelson (1941) theory that relates H-O theory of international trade to the wages paid to the skilled and unskilled workers, maintains that an increase in the relative price of the skilled-labour intensive product will increase the wage rate of skilled workers relative to both commodity prices and reduce the wage rate of the unskilled workers relative to both commodity prices. If there is an increase in the relative price of skill intensive product that raises the skilled-unskilled wage ratio then the skilled workers will be better off regardless of how their income is spent on the two products, as their wages will rise relative to both commodity prices. On the contrary, the unskilled workers will be worse off as their wages will fall relative to both commodity prices. By combining H-O proposition with the S-S theory, it is possible to see how trade affects the domestic wage ratio. The developed country has a comparative advantage in the product intensive in its relatively abundant factor, skilled workers. As the borders of the developed country open to the developing countries, the price of the skilled labour intensive product increases in the developed country relative to the price of the unskilled intensive product. As the Stolper-Samuelson (S-S) theorem suggests, trade will increase the relative income of the abundant factor and reduce that of the scarce factor. The developed country gains from trade and the gains of the skilled workers surpass the losses of the unskilled workers. Thus, the developed country faces increasing wage inequality between the two factors of production without a sufficiently elaborate political system to compensate for the loss of the unskilled labour force, which is the scarce factor in the developed country.

Figure 4.2 (The Lerner-Pierce diagram (Lerner, 1952)) provides a better understanding of the S-S theory involving two trading countries. The description is following Berman, Bound, and Machin (1998). Here, the unit-value isoquants ZZ and FF shows the combinations of inputs (skilled and unskilled labour) that produce one dollar of Pharmaceuticals and Footwear, respectively, in autarky. The line AB is tangent to these curves that describes zero profit combinations of inputs at equilibrium wages. Its slope is the wage ratio – W_U/W_S. In the Figure 4.2, the steeper slope of the ray from the origin to the tangency point represents optimal skilled-unskilled combination for good Z and the flatter slope of the corresponding ray for good F, illustrates the differing factor intensity in the production of these two products. The slope of any ray from the origin gives the ratio of skilled to unskilled labour employed in the production of the corresponding product. Hence Z is the skill intensive and F is the unskilled labour intensive product, as indicated by the steeper ray (S/U)Z and the flatter ray (S/U)F, respectively.

Figure 4.2 Stolper-Samuelson Model in a Small Open Economy Specification

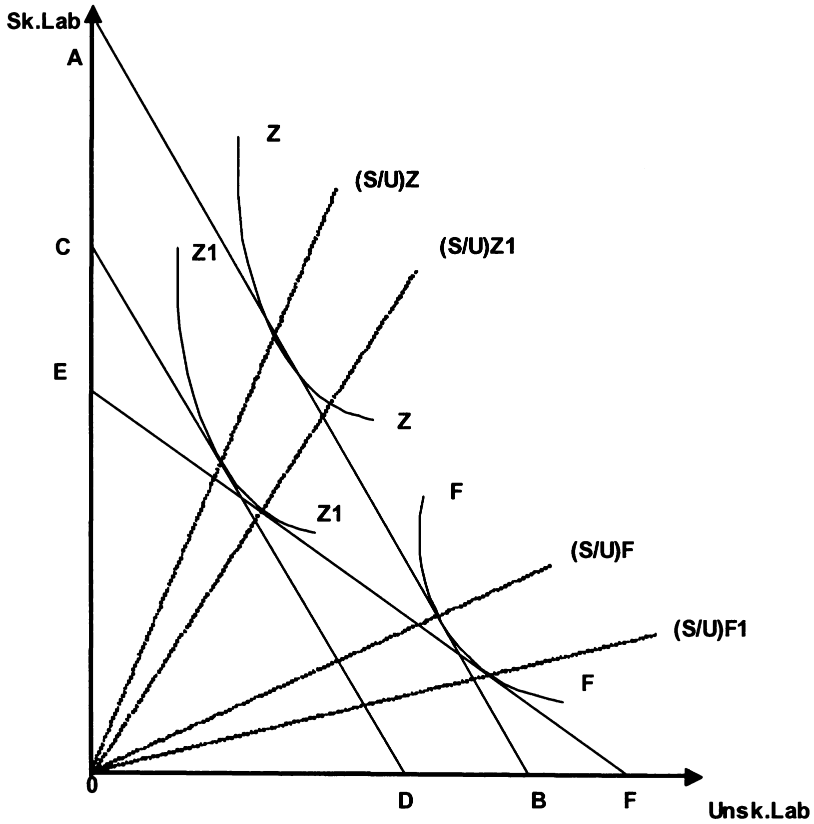


Figure 4.2

To elaborate the Stolper-Samuelson effect, we consider that a skilled labour abundant country opens its borders. The H-O theory implies an increase in the relative price of skill-intensive product, Z. This price change is reflected in the inward shift of ZZ to Z1Z1, as fewer inputs are required to produce a dollar worth of Z. Preserving zero profit condition, relative wages of skilled labour increase, a change reflected in the decrease in W_U/W_S as the line of tangencies shifts from AB to EF.

The resulting rise in the relative wage of skilled workers would cause a reduction in the use of skill (lower skilled-unskilled ratio) in production of each commodity. This is illustrated by the flatter rays, (S/U)Z1 and(S/U)F1, from the origin to the new equilibrium point for each product. Only in this way, enough skills will be released in the unskilled intensive sector, F, and enough skill will be economised in the skill-intensive sector, Z, for the composition of production shift away from F to Z. This is the theoretical basis the trade economists use to attack freer trade for causing rising wage inequality in the developed countries. One point to note here is that S-S theory implies economy wide higher relative skilled wages with lower skilled-unskilled labour ratio.

Given that the S-S effects are at work with trade liberalisation, Australian unskilled workers would face falling relative wage or rising unemployment if the wages are rigid and the labour market does not clear. However, S-S theorem will not hold under the following circumstances.

Firstly, the S-S effects would hold only if the countries involved in trade possess similar relative factor endowments. If the developed country has a very high ratio of skilled workers then it will specialise in pharmaceutical products and import all the footwear. On the contrary, if the developing country has a very high ratio of unskilled workers it will produce only footwear. In such a situation, the S-S theory will not hold. In brief, if each country completely specialises in producing the product in which it enjoys comparative advantage, and imports the other product from its trading partner rather than producing it at home, then the S-S theory will not hold any longer. Secondly, the possibility of factor reversals is also ruled out for S-S theorem. That is, production of one product cannot be unskilled-labour intensive at one price and skilled labour intensive at another price. Thirdly, the technology of production has to be the same in the trading countries. If the technology in one country were superior to technology in another country, then in the country with superior technology, both the factors of production (in this case, skilled and unskilled workers) would enjoy higher wages before and after the trade. This is simply because technological advancement marks increased productivity of the skilled and unskilled workers in that country.

The factor price equalisation theory, which is an extension of the S-S theory, predicts that when two countries start trading, the relative prices of the two factors of production (in this case, skilled and unskilled wages) converge in the developed and developing countries. This theory states that free trade will equalise not only commodity prices but also the prices of individual factors between the two countries, so that all unskilled workers will earn the same wage rate and all skilled workers will earn same wage rate in both the countries even if workers cannot move freely across these countries. Trade makes this possible as the factors of production that cannot cross borders between countries end up being implicitly traded between countries in commodity form. Developing country lets the developed country use some of its abundant factor, i.e., unskilled workers, not by selling the unskilled workers directly but by trading goods produced with a high ratio of unskilled to skilled workers in exchange for goods produced with a low unskilled-skilled ratio. More unskilled workers are embodied in a developing country's exports than in its imports from the developed countries and conversely, more skilled workers are embodied in a developed country's exports. Thus, the developing country is indirectly exporting its unskilled workers. Given this scenario, it is not surprising that trade leads to equalisation of the two countries' factor prices. Three assumptions are crucial to the prediction of factor price equalisation: 1) both countries produce both goods; 2) technologies are the same in two countries; and 3) trade equalises the prices of goods in the two countries i.e., there is no trade barriers (tariff, quota etc.) and no transportation costs.

Drawing on this theory it has been argued that increased trade based on comparative advantage with developing (low wage) countries would cause wages of unskilled workers to fall in Australia resulting in rising wage inequality among the skilled and unskilled workers.

New theory of International Trade: The Intra and Inter-Industry Trade

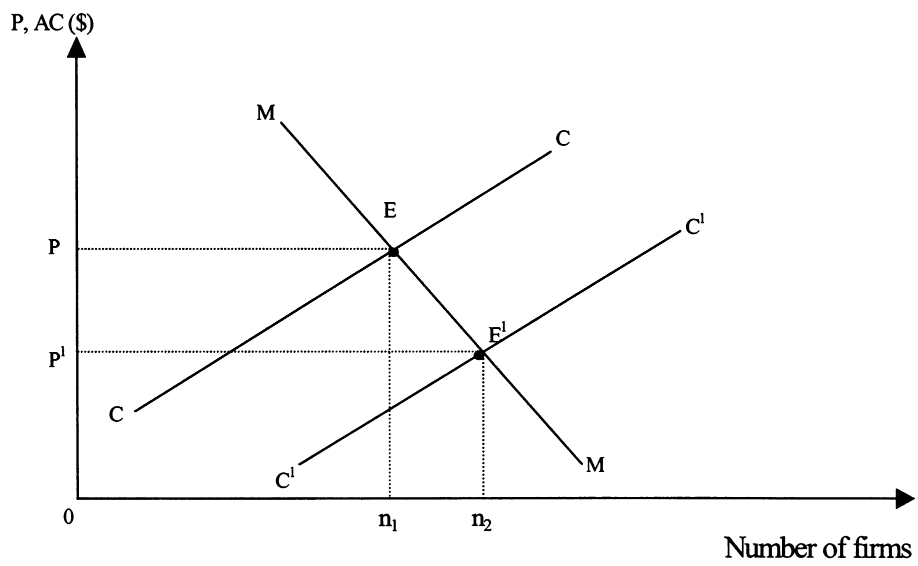
International trade theories suggest that when two countries open their borders to each other the gains from trade flow from expanded markets or from the comparative advantage in the production of specific goods. Ricardo's theory of comparative advantage (Ricardo, 1817) is viewed as a positive theory and helps predict, in the first place, the direction of trade. The theory suggests that a country exports the good embodied with lower comparative opportunity cost determined by its technology. In the second place, the theory helps to predict the terms of trade, as the country relies on its comparative cost ratios. From a normative viewpoint, the theory implies that citizens of a country are better off with trade, the extent of which is determined by the gains from trade. The gains from trade, in turn, depend on the degree to which the terms of trade exceed the domestic comparative cost ratio. H-O theory adds to the comparative advantage theory of trade stating that a country would produce and export the product that is intensive in its abundant factor. For example, developed countries are more likely to produce and export the products those are skilled-intensive, as these countries are abundant in skill as compared to the developing countries. According to this theory, the developed countries would have comparative advantage in skilled-labour intensive products and the developing countries would have comparative advantage in unskilled-labour intensive products. Thus, trade between developed and developing countries begins based on their respective abundance in factors of production and this trade is called inter-industry trade. S-S and the factor price equalisation theory adds to the H-O theory suggesting that apart from the advantages of trade based on comparative advantage, there will be falling real wages of unskilled workers relative to the skilled wages, raising the wage inequality in the developed country. In case of rigid wages the effects will be increasing unemployment as discussed above.

The new trade theory explains the basis of trade between two countries that are abundant in similar factors of production. For example, the theory explains how trade can take place between two developed countries that are capital abundant (or skill abundant in the context of this study). The theory suggests that the countries would produce differentiated products of the same industry and as trade begins the countries would have a larger market (domestic plus foreign) for their products. After they begin trade, each country produces one of the two differentiated products rather than producing both and the cost per unit of production declines as more are produced. Trade expands the market for each product (of the same industry) produced in the two countries and gain from trade originates from the reduction in cost per unit of production. This type of basis for trade is called intra-industry trade.

Figure 4.3 provides further explanations to aid understanding of the theoretical underpinnings of intra-industry trade. In Figure 4.3, the line MM shows the negative relationship between the total number of firms in the industry (N) and the price of the product (P_1) in a closed economy. Line CC represents the positive relationship between the number of firms and their average costs (AC) of production for a given level of industry output. The reason for the positive slope of CC is that, when more firms produce a given level of output, each firm's share of the industry output diminishes, and hence, each firm incurs higher average costs of production. In this closed economy, equilibrium is obtained at point E, which represents the point of intersection of the lines MM and CC.

When the countries open their borders and become part of a much larger integrated world market, firms in each nation can specialise in the production of a smaller range of products within each industry and face lower average costs of production. Mutually beneficial trade can then take place even if countries are identical in factor endowments and technology. Consumers would also be benefited from lower product prices and larger range of commodities. This is shown by the downward shift of the curve CC to C^1C^1 in Figure 4.3. The new equilibrium is at E^1 with price P_2, which is lower than P_1. Gains from trade would be dominant if the trade is intra-industry and when the country's trading partners are similar in their relative factor supplies, for example, similar in capital-labour ratios, skill-levels etc.

Figure 4.3 Diagrammatic Representation of Intra-Industry Trade



The gains from trade would also be dominant if the economies of scale and product differentiation are important. Since the developed trading partners have similar technologies and resources, there is often no clear comparative advantage within an industry. In these cases, most of the trade takes the form of two-way transaction within industries driven largely by economies of scale – instead of taking the form of inter-industry trade that is driven by comparative advantage. Intra-industry trade with expanded markets motive cannot alone predict the direction of trade, i.e., it fails to predict which country will produce which of the differentiated products within the industry.

Intra-industry trade produces extra gains compared to what trade based on comparative advantages does, because by intra-industry trade countries gain from expanded markets. Also, intra-industry trade yields similar skilled-unskilled labour endowments as well as returns to different types of labour of the trading partners. In other words, if the pattern of trade between two countries is more towards intra-industry, then the effects of trade on wage distribution would be small and both the skilled and unskilled workers would gain from trade. The stronger are the economies of scale and higher is the product differentiation, the larger is the gains from intra-industry trade. This type of trade is more frequently observed in trade involving sophisticated manufactured goods rather than raw materials or more traditional products such as clothing or footwear. As a consequence, trade among advanced developed countries would have lesser effects on skilled-unskilled wage ratio. On the other hand, trade between developed and developing countries are expected to be based on comparative advantage and would result in increased wage inequality among the skilled and unskilled workers in the developed country.

For the empirical analysis of the effects of trade based on comparative advantage and of the existence of S-S effects or intra-industry trade, data from different sources have been used in this study. The following section describes the data sources and the empirical specifications of the measurement of trade effects on the labour market.

4.3 Data Description and Model Specification

Data sources and Definitions

Data have been gathered from different sources for empirical analysis presented in this chapter. This section provides a comprehensive description of data sources and variable construction.

Data on GDP and Industry Value Added for Australia over the period 1982-83 to 1998-99 have been obtained from Australian Bureau of Statistics (ABS) spreadsheets. The ABS tables that contain these data are 520611a, 5206015, 17, and 47. Data on per capita income, GDP, exchange rates of currencies of different countries with Australian dollar for the year 1995 are available from DX Economic Database (World Bank, 1999). In the DX database the values are presented in 1995 U.S. dollars and these have been converted into Australian dollars using the exchange rates of 1995. Distances of various capital cities of Australia's trading partners from Sydney, Australia, have been measured by using the software MapW (1993-94).

The labour force data of Australia have been obtained over the period 1986-87 to 1998-99 from ABS Tables 9C and 9I. One exception has been for the year 1982-83. For this year, data on manufacturing employment has been obtained from Industrial Statistical Database (Revision 2) maintained in United Nations Industrial Development Organisation (UNIDO) for three-digit International Standard Industrial Classification (ISIC) industries[4].

Australia's Total Manufacturing Exports and Imports data for various years over the period 1982-83 to 1998-99 have been obtained from the publications of DFAT (DFAT, 2000a). Manufacturing exports and imports consist of the trade in the sectors falling under the Standard International Trade Classification (SITC) codes of 0 (excluding Live Animals), 1, 5, 6, 7, and 8. The information on Australian manufacturing trade for various years over 1982-83 to 1998-99 has been obtained from the ABS Cat. No. 5422.0.

[4] The source of UNIDO data is ABS data. The data on labour force for the year 1982-83 was not available electronically from ABS and hence UNIDO data have been used for this year's labour force.

The information on exports and imports of Australia with different countries at different industry levels for the year 1995-96 has been collected from DFAT (DFAT, 2000b). The disaggregated trade data published by DFAT is classified in two forms: Trade Exports Classification (TREC) and SITC, Revision 3. Data that are classified according to SITC R3 are shown in three-digit level (DFAT, 2000b). The industry level trade data is only reported by DFAT for those countries with which Australia has significant amount of trade in that sector.

To convert the time series export and import data in constant price of 1989-90, Export Price Indexes and Import Price Indexes have been used. These indexes are obtained from Table 9 of ABS time series online database.

For the period following 1983, developed countries have been defined as a group of economies including European Union, the U.S.A., Japan, and New Zealand. For the period prior to 1993, the group of developed countries has been classified as countries of European Community (EC), European Free Trade Area (EFTA), the U.S.A., Japan, and New Zealand. Developing countries have been categorised as the countries with low income as defined in ABS in Catalogue No. 5422.0 of the relevant years.

Data on wages and number of employees in different industries and countries for the year 1995 have been obtained from the UNIDO databases of three and four-digit ISIC industries (Revision 2). Wages and employment data for textiles (321), clothing (322), footwear (324), machineries (382), electronics (383), and chemical industries (351) have been obtained from the three-digit UNIDO database. Data for medicinal and pharmaceutical products (3522) and computers (3825) have been obtained from UNIDO four-digit database. Countries for which data for 1995 are not available, data available from the nearest year within 1990s have been taken.

For the countries with data unavailable in 1995 or in the nearest year (as described above) at four-digit level of industry breakdown, data from three-digit ISIC industries have been used. In the medicinal & pharmaceutical industries (ISIC 3522, Rev.2 or ISIC 2423, Rev. 3), no data is available for Puerto Rico and Namibia at three or four-digit levels of industry classification breakdown. Consequently, data on wages and employment in industrial chemical, which is the closest category available for 1995, has been used for these two countries. Similarly, for Switzerland, data on basic chemicals (ISIC 241, Rev.3) has been used for medicinal & pharmaceuticals industry.

For computer & computer parts industry (ISIC 3825, Rev. 2 & ISIC 3000, Rev. 3) no information on wages and employment were available for Switzerland. Hence, data on electric motors, generators, & transformers (ISIC 3110, Rev. 3) have been used as proxy. There was no information available on disaggregated industry level wages for China after 1986. Therefore, the wages of total manufacturing sector has been taken as a proxy for all the industries.

Consumer Price Indexes for the clothing & footwear industries over the years 1982-2000 have been available from ABS Cat. No. 6401.0. Producer Price Indexes for the same industries and years have been obtained from the ABS Cat. No. 6401.0. These indexes are reported in quarterly basis and hence have been converted into annual indexes taking an average of the indexes of four quarters for each year. ABS changed the base year of the producer price indexes from 1980-81 to 1989-90 in its publications of more recent years. Hence, the entire series of these indexes has been converted with a common base year of 1989-90 =100. GDP deflators for Australia over the period 1982-2000 have been obtained from World Bank World Tables. These indexes are also reported in quarterly form and then have been converted to annual figures. The base year for GDP deflators has also been converted from 1996-97 to 1989-90 to match the base year of Consumer Price Index and Producer Price Index.

Information on wages and employment of skilled and unskilled labour in Australia for some selected years over the period 1986 to 2000 has been obtained from the Survey of Employee, Earnings and Hours (unpublished) provided by ABS.

Input-Output matrices of 1986 and 1996 have been obtained from ABS Cat. No.5209.0. Information on total Australian product, exports, and imports according to three-digit industry codes has been obtained from the same source. To deflate the final demand, Consumer Price Indexes (CPI) of the corresponding years have been used. The CPIs for 1986 and 1996 have been obtained from ABS Cat. No.6401.0. Again, the base year for the entire series was required to be changed from 1980-81 to 1989-90. To convert the base years the conversion factors have been used that provided by ABS in the above-mentioned catalogue. Net Imports of the years 1986 and 1996 have also been deflated using the import price indexes for manufacturing industries of the corresponding years obtained from ABS Cat. No.6414.0. For these import price indexes, base year was changed to 1989-90.

One important point to note is that ABS has changed its industrial classification scheme from ASIC to ANZSIC. Also, the industry classification for Input-Output tables changed over the period included in this study, i.e., from 1986 to 1996. Hence, it has been difficult to perform any comparison of industries before and after the changed industrial classification. The input-output industry classifications of 1986-87 have been transformed to match the employment in 1986 based on ASIC schemes. The input-output industry classifications of 1996-97 have been transformed to match the employment of 1996-97 based on ANZSIC breakdown. ABS catalogue number 5209.0 contains detailed concordance of the input-output industry classification and their corresponding ASIC (for 1986-87).

The same catalogue also provides concordance of Input-Output industry classification and ANZSIC industries (for 1996-97).[5] Fortunately, counterfactual trade measurement does not require any direct transformation of ASIC to ANZSIC, which would be more troublesome as no clear concordances between ASIC and ANZSIC are available from ABS. However, as the transformations used in this study contain three-digit industry categories, the bias, if any, would be reduced since the industry variables have been aggregated at two-digit level of manufacturing industries. Also, it proves to be a good instrument to analyse the factor content of trade measurement in Australia before and after trade liberalisation.

Table 4.4 presents the volume of exports and imports and their ratios to total exports, GDP, and manufacturing value-added in the year 1995, for eight manufacturing industries of Australia. These eight industries have been selected for analysing

[5] For example, the printing & services to printing (2401) in Input-Output industry classification would be printing & services to printing (2411-3) in terms of ANZSIC. Similarly, the plaster & other concrete products (2604) in I-O industry classification contains the plaster products manufacturing (2632), concrete pipe & box culvert manufacturing (2634) and concrete product manufacturing n.e.c. (2635) of ANZSIC scheme.

Australia's trade patterns with its major trading partners and their effects on the labour market.

Table 4.4: Exports, Imports of Eight Industries and Their Ratio to Total Exports, Imports, GDP and to Manufacturing Value Added for Australia, 1995

Industry	Exports '$m	Imports '$m	Exports to Total Exports (%)	Imports to Total Imports (%)	Exports to GDP (%)	Imports to GDP (%)	Exports to Manufac-turing Value Added (%)	Imports to Manufactur-ing Value Added (%)
Medicinal & Pharma-ceuticals	711.38	1729.5	0.936	2.223	0.14	0.34	1.047	2.544
Textiles	318.85	2041.1	0.42	2.624	0.063	0.402	0.469	3.003
Computers etc.	1690.6	5199.3	2.224	6.684	0.333	1.023	2.487	7.649
Clothing Etc.	7165.3	1600.7	9.427	2.058	1.41	0.315	10.54	2.355
Chemicals	2674.6	7840.3	3.519	10.08	0.526	1.543	3.935	11.53
Machineri-es	2542.6	10068	3.345	12.94	0.5	1.981	3.74	14.81
Electronics	483.23	3434.4	0.636	4.415	0.095	0.676	0.711	5.052
Footwear	26.392	505.52	0.035	0.65	0.005	0.099	0.039	0.744
Total (Eight Industries)	15613	32418	20.54	41.67	3.073	6.38	22.968	47.69

Source: Author's Calculations using DFAT publication of trade data (2000) and ABS spreadsheets

From Table 4.4, it is observed that only clothing industry had trade surplus (exports greater than imports) in 1995. Share of exports of clothing in total exports, GDP and manufacturing value-added are also large compared to the export shares for other industries. Exports of clothing contributed 9.43 percent in total exports. These are 1.41 percent of GDP and 10.54 percent of total manufacturing value-added. On the other hand, machineries and chemicals industries have the largest share of imports to total imports, GDP and manufacturing value-added (12.94, 1.98 and 10.08 percent, respectively) among the eight industries. The table also shows that total imports of the eight industries are 6.38 percent of GDP while total exports to GDP are 3.07 percent. Share of exports of these industries to manufacturing value-added is about 23 percent and share of imports to manufacturing value-added is around 48 percent. Unskilled intensive footwear industry has the share of exports to total exports of 0.035 percent, which is the smallest exporting sector among the eight industries. Share of footwear imports to total imports is also small (0.65 percent).

Model Specification

Existence of Stolper-Samuelson Effects in Australia

To investigate the existence of S-S effects in Australia the relative consumer and producer prices of selected manufacturing products[6] could be compared. In this study the relative consumer price ratio (measured as the ratio of the consumer price index of the concerned product to the CPI) and the relative producer price index (measured as the ratio of the producer price index of the same product to the GDP deflator) have been used for two manufacturing industries, viz., clothing & footwear and motor vehicles. These are the only manufacturing industries for which the producer price index is available over the period 1982-83 to 1999-00. Consumer prices include the average of the producer prices and the import prices. When comparing the relative consumer and producer prices of a product over time, if the consumer price shows any downward movement and the producer price remains steady, then there must be a relative decline in the import prices to the domestic prices. This shows the evidence of the existence of S-S effects in that industry. The results have been presented in Figure 4.4 and 4.5 in section 4.4.

To investigate the S-S effects in Australian manufacturing industries more closely, the trend of relative skilled-unskilled wages over time is required to be examined since international trade would affect the relative return on different factors of production, such as, wages of skilled and unskilled workers. According to this trade theory, increased trade with low-wage countries would put upward pressures on skilled wages of the developed country, driving down the relative wages of unskilled workers and resulting in widening the wage gap of skilled-unskilled workers. The rising relative wages of skilled workers, if observed, would result in a fall in the ratio of skilled to unskilled workers used in that industry, provided trade is the only cause to distort the labour market as described in Section 4.1. Weekly earnings of different two-digit ANZSIC industries have been defined as weekly earnings of two-digit ASCO groups[7] and have been used in this chapter. The weekly earnings of the workers with managerial status have been used as the skilled wages and the weekly earnings of the workers with

[6] Fahrer and Pease (1994) used this methodology to investigate the trade effects in Australia. Their study covered the period from 1982 to 1993.

[7] The data is based on information relating to sample of employers and employees for each year.

non-managerial status have been used as the unskilled wages in two digit industries. Similarly, to construct the skilled and unskilled worker groups of two-digit ANZSIC industries, the workers with managerial status has been used as the skilled and with non-managerial status as the unskilled workers.[8] ABS cautions about the volatility of this fine level of disaggregated data due to small sample bias. Hence, to maintain the reliability of the analysis, the skilled-unskilled ratios have not been reported in the tables if the relative standard errors are very large. The empirical evidences of S-S effects in Australia have been presented in section 4.4 of this chapter.

Factor Content Measurement of Trade Effect in Australian Manufacturing Industries

The most commonly used method of estimating the effects of trade on labour markets is to calculate the factor content of trade. This method has been used to find out how much of skilled and unskilled labour or total labour would be used in the production of country's net imports (imports minus exports), if these net imports were produced domestically. The difference between export and import content (net trade content) has been interpreted as the impact of trade on the demand shift of skilled-unskilled workers by comparison to what it would have been in absence of trade (Wood, 1995). In measuring the factor content of trade, the assumption of fixed net imports to final demand ratio for the base year and the current year has been conventionally used by trade economists.

In this chapter, counterfactual measurement of trade has been used as a more formal approach to measure the effects of increasing import penetration on employment in Australia. This method assumes that the import penetration (as a percent of final demand) does not increase after the base year.[9] The base year used in this analysis is

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[8] Another possible method has been used to construct the skilled and unskilled wages and employment using the data set. In that method, the weighted average wages of generalist managers to other associate professionals have been defined as skilled wages and the weighted average wages of mechanical fabrication engineering to other labourers & related workers have been defined as unskilled wages. The same definitions have been used for the skilled and unskilled employment. The skilled unskilled ratios, using this method, are similar to the ratios used for this study.

[9] This method closely follows the work of Sachs and Shatz (1994). The separate effects on skilled and unskilled employment of international trade for all the two-digit manufacturing industries (ASIC and ANZSIC) in Australia rather than only the total employment (skilled plus unskilled) effect have been presented in this study.

1986, which has been compared with the current year, 1996. The rationale used in calculating the counterfactual change in employment in different sectors is that if the imports relative to final demand remain at the base year level in the current year, then in order to meet the increased level of final demand of the current year the domestic production and hence employment would have to be increased. The increased labour demand due to the counterfactual measurement can be considered as the amount of job losses that results from the increased volume of trade between 1986 and 1996[10]. The results from counterfactual trade measurements have been analysed in section 4.3 of this chapter.

Trade pattern and relative wages of trading partners

One important analysis of trade effects on Australian manufacturing performed in this chapter has been the estimation of the relationship among the relative wages of Australia's trading partners to Australian wages (thereby measuring the income status of trading partners compared to Australia). This study also examines the trade pattern of Australia with its trading partners measured in terms of G-L index in few carefully chosen manufacturing industries. To this connection, the main concern has been to address the extent of the effect of trade on labour market given the income status of the Australia's trading partners (low-wage country and high wage country). To examine the nature of Australian trade (i.e., whether intra or inter industry trade) with its trading partners, the intra-industry trade index for Australia with its 52 major trading partners for the year 1995 has been calculated for eight different manufacturing industries. If the trade pattern of Australia follows the proposition of the 'new trade theory' as discussed in section 4.3, then the G-L indexes are expected to be close to zero for developing countries (for example, for China and Indonesia) and close to one for developed countries (such as, for U. K. and Japan).

The standard formula for calculating the level of intra-industry trade has been given by Grubel and Lloyd (1975). In their original work, Grubel and Lloyd (1975) calculated the index for various industries in ten industrial countries for the year 1967. The Grubel-Lloyd (G-L) index for the *i*-th industry can be measured as:

[10] The method used to measure the factor content of trade has been elaborated in the appendix A4.I.

$$GLInd_i = ((X_i + M_i) - |X_i - M_i|)/(X_i + M_i)$$

Or,

$$GLInd_i = 1 - \frac{|X_i - M_i|}{X_i + M_i} \tag{4.1}$$

where, X and M represent the value of total exports and imports, respectively. The sign $|\quad|$ denotes the absolute value. The G-L index can range between zero to one. The higher the value of the index, the more intra-industry is the trade between the two countries and the smaller is the value of the index, the more inter-industry is the trade between the trading countries. To be more precise, intra-industry trade takes place when $X_i = M_i$, that is when the exports of an industry is exactly equal to the imports of the same industry. On the other hand, inter-industry trade is the absolute gap between exports and imports, $|X_i - M_i|$, that is, if $X_i > M_i$ or $M_i > X_i$. On the one extreme, an index of 0 shows that there is no intra-industry trade (i.e., trade consists of either only export or only import), and on the other, when the index equals to unity, it shows that there is no inter-industry trade (i.e., exports and imports are exactly equal).

The 'new trade theory' states that a developed country's trade with other developed or high wage countries will be more intra-industry in nature, i.e., in differentiated products of the same industry. On the other hand, the theory suggests that developed country's trade with developing or low-wage economies will be more inter-industry, i.e., based more on comparative advantage. Given this proposition, intra-industry trade is not expected to cause significant net job losses or significant shift in the wages of workers based on their skill level, as is expected in case of inter-industry trade that takes place on the basis of comparative advantage.

There is however, a serious shortcoming in using intra-industry trade index. The indexes would vary widely depending on how broadly an industry or product group has been defined. Hence, the growing trade between low-wage and high-wage countries could be classified as intra-industry even though it is actually driven by comparative advantage (Krugman and Obstfeld, 2000). For example, U.S. can produce computer chips, ship them to some Asian low-wage countries where these are assembled into computers and then the computers could be shipped back to U.S. In such a case, both the exports and imports would be classified as 'Computers and Related Devices' and the trade index would indicate intra-industry trade. Thus, trade index should be used with caution. Nevertheless, the G-L index is useful in measuring differences in intra-industry index in different industries. Also, intra-industry trade index can be affected by some factors other than similarities in the development levels or economies of scale. For instance, the factors that affect trade, such as, distance, income levels of the trading partners, exchange rates etc., will also affect the G-L index.

It would be of interest to establish a general relationship between Australia's trade pattern (measured by G-L index) and income status of its trading partners (where income status is to be identified by the corresponding country's relative wage status. That is, whether the country falls in the low wage, medium wage or high wage category). The relative wages of different countries, measured as wage rates of the trading partners to the wage rates in Australia in specific industries, would be high with high-income countries and vice versa. If the relationship between G-L index and relative wages of Australia's trading partners is found to be positive then it would imply that international trade with high wage countries would be more of intra-industry in nature. That is, as the relative wages of the trading partners increase, Australia's trade with that country becomes more of intra-industry in nature (i.e., G-L index rises). Similarly, it would imply that Australia's trade with low wage countries is more of inter-industry in nature, i.e., as the relative wage of trading partner decreases the value of the G-L index declines. Consequently, increased trade with low-wage countries would cause significant net job losses, and would shift income towards skilled workers from unskilled workers in Australia, as predicted by the H-O and S-S or factor price equalisation theories.

In their study of trade effects on jobs in the U.S. manufacturing industries, Sachs and Shatz (1994) found positive relationship between the G-L index and relative wages of trading partners. They identified a significant positive relationship between trade pattern (measured by G-L index for the manufacturing sector as a whole) and relative wages of different trading partners of U.S. for the year 1990. Their result revealed that the U.S. trade with low wage countries is mainly based on the comparative advantage and hence, could cause manufacturing job losses. However, Sachs and Shatz (1994) did not control for any other determinant of trade in their study. Ignoring the other determinants of trade may have had significantly affected their results. Their study also does not measure the effects of trade on trade pattern of each individual industry (they measured the effects of total trade on total trade pattern). Therefore, their results could have been severely biased due to the inherent weaknesses of G-L index discussed earlier.

To remedy these weaknesses, few additional explanatory variables have been included in this study, namely, size of various economies, exchange rates, and distances. A scale variable for openness has been included to partially correct for the bias accruing from the inability of the G-L intra-industry trade index to account for the volume of trade. The regression model indicating the relationship between the trade pattern of Australia and the type of economies denoted in terms of relative wages for i-th industry for the year 1995 is as follows:

$$GLInd_{ij} = \alpha + \beta_1(W_{ij}/W_{iAus}) + \beta_2 \ln(GDP_{Aus}*GDP_j) + \beta_3 (ExchangeRate_j) + \beta_4 \ln(Distance_j) + \beta_5 ((X_j + M_j)/GDP_{Aus}) + \varepsilon_i \quad (4.2)$$

where, W_{ij} and W_{iAus} stand for wage rate in country j and in Australia for i-th industry, respectively.

Ordinary Least Squares (OLS) has been used to estimate equation (4.2) for eight different industries. Robust standard errors have been estimated and presented in the estimation results[11] to correct for heteroscedasticity (i.e., explanatory variables are dependent and hence related with error terms).

In the general form of gravity equation, it is stated that the bilateral trade between two countries are proportional to the product of the outputs produced by those two countries. Thus, countries with similar relative sizes tend to trade more with each other (Tinbergen, 1962; Loungani, Mody and Razin, 2002; Feenstra, 2002). Hence, the log of

[11] As the best, linear, and unbiased estimator (BLUE), one of the classical assumptions of OLS is homoscedasticity, or in other words, the variances of estimates are constant. This assumption is unlikely to hold for industry level data. Hence, assuming variances are not constant or heteroscedasticity, the robust estimates (Huber/White/Sandwich estimates) of standard errors (square roots of variances) have been estimated and reported in this study.

the product of Australia's GDP (GDP_{Aus}) and GDP of the *j*-th partner (GDP_j) of 1995 is used as an explanatory variable of G-L index and the expected sign of the coefficient is positive.

Log of distances[12], which is again a standard gravity term, between Sydney and the trading partners' capital city measured in kilometers, have been included in the regression equation (4.2). Gravity models postulate that bilateral international trades are not only related to the size of the two economies, development status, but also to the distance between the trading countries. The reason for why distance matters lies in the fact that distance could be considered as a proxy for transportation costs. In all the studies using gravity equation, the distance coefficient appears with a negative sign (implying that greater is the distance lower is the trade) ranging from -1.5 to -0.8, (Loungani et al. 2002). Hence, the expected sign of the distance coefficient is negative.

Another explanatory variable used in the equation (4.2) represents the exchange rates of the currencies of the trading partners with Australian dollars in the year 1995. The effect of exchange rate and exchange rate volatility on trade had been a concern as majority of the trading nations embraced a regime of floating exchange rate by 1995 (McKenzie, 1999). If the country's currency appreciates, imports would be cheaper and exports would be less competitive for that country. Hence, imports of that country would increase whereas exports would diminish. The converse will be the case with depreciating currency. Keeping these considerations in mind, the exchange rate is included in the regression and its expected effect on G-L index would be ambiguous. The effect would depend on whether the exports are greater than imports or vice versa. When the volume of exports is greater than imports then the effect of exchange rate on G-L index would be negative and when imports is greater then the effect would be positive. The significance of exchange rates on G-L index would actually depend on how much the exchange rates can affect the volume of exports and imports of different products in different countries.

The last explanatory variable used in the regression equation is the industry specific trade (both exports and imports) from each country as a share of Australia's GDP, that

[12] Distances have been measured based on the author's calculations of the straight-line distances from Sydney, Australia to the capital city of the trading partner j, using the software MapW.

is,$(X_{ij} + M_{ij}) / GDP_{Aus}$, to partially correct for the weakness of G-L index that it does not account for the volume of trade.

4.4 Results and Analyses

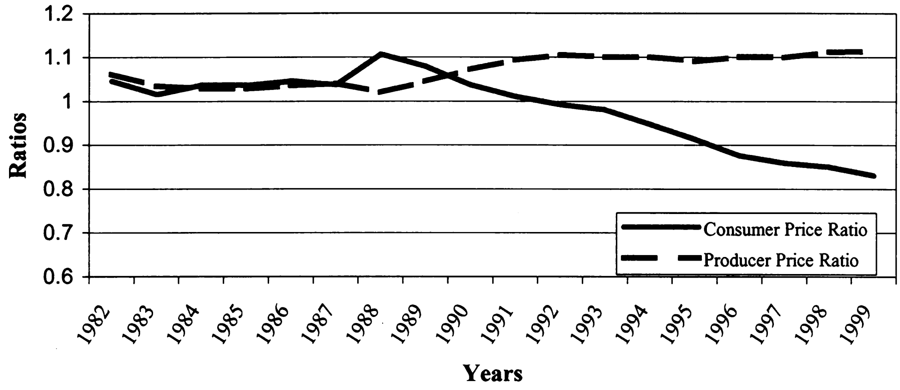
Empirical findings on the existence of Stolper-Samuelson effects in Australia

To investigate the existence of S-S effects in Australia, as discussed in section 4.3, the relative consumer and producers prices of selected manufacturing products[13] have been used. The relative consumer price ratio (measured as the ratio of the consumer price index of the concerned product to the CPI) and the producer price ratio (measured as the ratio of the producer price index of the same product to the GDP deflator) for two manufacturing industries, clothing & footwear and motor vehicles, have been presented and compared. Note that only two manufacturing industries have been analysed to find the possible presence of S-S effects as because the producer price indexes are available over the period 1982-83 to 2000 only for these two manufacturing industries. The results have been depicted in Figure 4.4 and 4.5.

In view of the earlier discussion regarding detection of S-S effects using the consumer and producer price ratios, it is expected that these two ratios would fall apart from each other should the S-S effects exist in Australian economy. If the gap between two ratios widen over time then it is likely that the industry encountered severe adverse effects on the wages and employment from increased trade, as suggested by the S-S theory. Figure 4.4 states that the relative consumer price for clothing & footwear has fallen sharply and consistently after the trade reform in 1989-90. However, the producer price ratio fell slightly before 1988 and then rose by ten percentage points by

[13] Fahrer and Pease (1994) used this methodology to investigate the trade effects in Australia. Their study covers the period from 1982 to 1993.

Figure 4.4 Relative Consumer and Producer Prices for Clothing & Footwear, 1982 to 2000



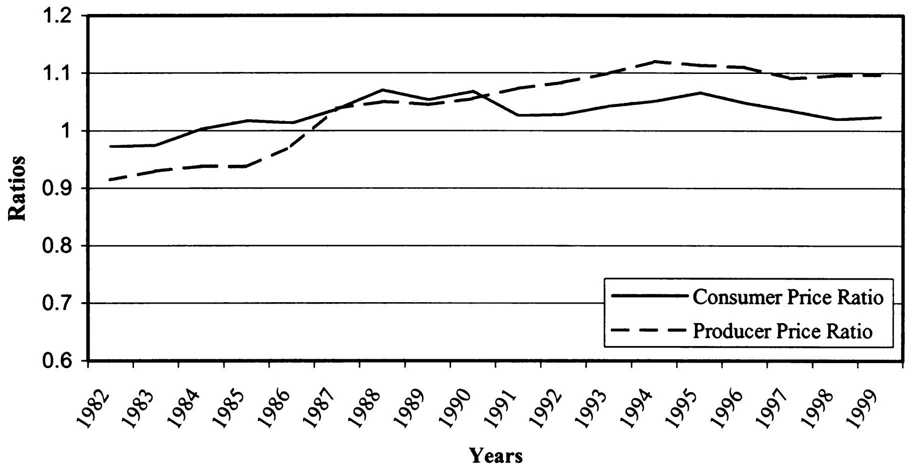
Source: Author's calculations as described in section 4.3

1992-93. In subsequent period, the producer price ratio remained almost steady with little or no change recorded. As a result, the gap between the consumer price ratio and producer price ratio widened gradually up until 1993 and more sharply from 1993 till the end of the decade. Altogether, this figure exhibits that there are evidences of the existence of S-S effects in Australian clothing & footwear industry owing to the fall in protection against world competition accorded to this industry.

Figure 4.5 shows that the relative consumer prices for motor vehicles were greater than relative producer prices at the beginning of the concerned period. By 1989-90, the producer price ratio became greater than consumer price ratio and remained steady until 1999. The consumer price ratio fell after 1980 and remained steady for the rest of the period. Hence, the gap between the two price ratios remained relatively constant over the period 1990 to 2000. This result shows that there is some evidence of S-S effects on motor vehicles industry due to reduction in protection given to this industry but the effect is smaller than that on the clothing & footwear industry. The S-S effect on motor vehicles industry remained almost the same since the introduction of drastic reduction in protection in 1989-90.

The figures also state that there has been evidence of stronger S-S effects in the relatively unskilled labour intensive clothing & footwear industry since the beginning of the gradual reduction of protection accorded to this industry. The effects have become worse as the protection has been declining over time. When the protection has started to decline in 1989-90 the import prices have fallen that has driven down the consumer prices of clothing & footwear in Australia, which confirms the fundamental argument of S-S theory of trade.

Figure 4.5 Relative Consumer & Producer Prices for Motor Vehicles, 1982 to 2000



Sources: Author's calculations using data from ABS Cat. No.6401.0 and 6412.0 for Consumer Price and Producer Price Indexes by Industry, respectively. Data on GDP deflator have been obtained from World Bank world tables DX Database and data on total Consumer Price Index (CPI) have been obtained from ABS online Spreadsheet: Table 1A.

Fahrer and Pease (1994) found similar results of S-S effects up until 1992-93 in the clothing & footwear and in motor vehicles industries for Australia. The findings of this chapter states that the evidence of S-S effects of trade are strong in unskilled intensive sectors up until the year 2000 and such effects are getting even stronger (can be seen from the increasing gap between the consumer and producer price ratios for the clothing & footwear industry) as the protection is gradually fading away. On the other hand, the motor vehicle industry, which is less unskilled intensive than the clothing & footwear industry, has shown some evidence of S-S effects although such effects did not get stronger over time.

Stolper-Samuelson Effects: Yet Another Look

The existence of strong S-S effects in the clothing & footwear industry but not that much in the motor vehicles industry raises concerns about the extent of the effects of increased international trade on Australian labour market. To investigate the S-S effects in Australian labour market, the trend of relative skilled-unskilled wages is required to be examined since international trade would affect the relative return on different factors of production, in this case, wages of skilled and unskilled workers. Trade with low-wage countries would put downward pressures on unskilled wages, driving down the relative wages of unskilled workers and resulting in wider wage gap of skilled-unskilled workers. Then, the rising relative wages of skilled workers caused by trade alone, if found, would result in a fall in the ratio of skilled to unskilled workers used in that industry as discussed in section 4.2 of this chapter.

First, to find the trend of relative wages among the skilled and unskilled workers in different manufacturing sectors in Australia for selected years over the period 1986 to 2000, the skilled and unskilled wage ratios by two-digit manufacturing industry have been presented in Table 4.5. The table shows that there are mixed evidences of effects of trade on wages. While in some industries the wage ratios have increased, in the other industries the wage ratios have declined. There has been a sharp rise in wage ratio in food, beverages & tobacco (21) and textiles, clothing, footwear & leather (TCFL) (22) industries over the period. A gradual rise of wage ratio is found in few industries, namely, wood & paper products (23), petroleum, coal, chemical & associated product (25) and other manufacturing (29) industries. The industries that experienced gradual decline of wage differential among skilled and unskilled workers include printing, publishing, & recorded media (24), non-metallic mineral products (26), metal product (27) and machinery and equipment (28) industries. It is seen that despite the increase in Australia's trade with developing countries, especially after the beginning of phased reduction in trade barriers since 1989, the wage inequality among the skilled and unskilled workers have not been increasing in all the manufacturing sub-sectors. The highest increase in wage inequality is found in the food, beverages & tobacco and TCFL industries, which are believed to be the most unskilled intensive industries among all the different categories of manufacturing industries.

Table 4.5 Ratio of Skilled–Unskilled Weekly Wages in Australian Manufacturing Sub Sectors, 1986-2000

Manufacturing Industry	1986	1993	1996	2000
21 Food, Beverage and Tobacco	1.61	1.78	2.05	2.27
22 Textile, Clothing, Footwear and Leather	1.72	1.81	2.09	2.03
23 Wood and Paper Product	1.53	1.36	1.66	1.70
24 Printing, Publishing and Recorded Media	1.49	1.41	1.48	1.28
25 Petroleum, Coal, Chemical and Associated Product	1.71	1.72	1.53	1.77
26 Non-Metallic Mineral Product	1.78	1.47	1.60	1.47
27 Metal Product Manufacturing	1.52	1.47	1.28	1.46
28 Machinery and Equipment	1.56	1.64	1.51	1.54
29 Other Manufacturing	1.31	1.47	1.41	1.46

Source: Author's calculations using ABS data based on Survey of Employee Earnings and Hours (unpublished).
Note: The definitions of Skilled and Unskilled workers are as described in the text. The wages are estimated average weekly ordinary time earnings provided by ABS (unpublished).

To complete the search for S-S effects in Australian labour market, as mentioned earlier, it is necessary to look at what is happening in the skilled unskilled employment ratio over the same time period in all the industries. Table 4.6 depicts the actual skilled and unskilled employment ratio by all manufacturing industries at two digit levels, for some selected years covering the period 1986 to 2000.

If S-S effects were the sole cause to raise the skilled-unskilled wage gap by increasing skilled wages and/or reducing the unskilled wages (explained by S-S or factor price equalisation theory), then the rising relative wages of skilled workers would compel all industries to substitute unskilled workers for skilled workers and the ratio of skilled-unskilled employment would be reduced (Lawrence and Slaughter, 1993). Table 4.6 shows that the skilled-unskilled employment ratio has increased in all the manufacturing sub-sectors except for the food, beverages, & tobacco industry. For this industry the ratio was 0.11 in 1986 and has increased to 0.12 by 1993. After 1993 the skilled-unskilled employment ratio in this industry has declined and by 2000 the ratio has been reduced to 0.09.

Table 4.6 Ratio of Skilled-Unskilled Employment in Manufacturing Sub-Sectors, 1986 to 2000

Industry	1986	1993	1996	2000
21 Food, Beverage and Tobacco	0.11	0.12	0.10	0.09
22 Textile, Clothing, Footwear and Leather	0.10	0.07	0.08	0.11
23 Wood and Paper Product	0.07	0.14	0.08	0.09
24 Printing, Publishing and Recorded Media	0.15	0.15	0.16	0.34
25 Petroleum, Coal, Chemical and Associated Product	0.14	0.17	0.13	0.20
26 Non-Metallic Mineral Product	0.10	0.18	0.12	0.16
27 Metal Product	0.10	0.12	0.12	0.15
28 Machinery and Equipment	0.12	0.15	0.14	0.16
29 Other Manufacturing	0.10	0.20	0.21	.. *

Source: Author's calculations using ABS data from Cat. No. 8221.0 and ABS data on Survey of Employee Earnings and Hours (unpublished).
Notes: The ratio of skilled-unskilled workers has been measured using the Survey of Employee Earnings and Hours data. The definition of skilled and unskilled workers has been described in the text.
*Not presented due to large standard errors reported by ABS (unpublished).

In the TCFL industry the skilled-unskilled employment ratio fell from 0.10 to 0.07 over 1986-1993 and then has started to increase and by the year 2000, the ratio has risen to 0.11. Comparing Table 4.5 with Table 4.6, it is observed that the food, beverages & tobacco industries has experienced rising wages of skilled relative to unskilled workers over the concerned period along with a falling share of skills in employment. Hence, it is evident that this industry is showing the existence of S-S effects from increasing trade after 1993 up until 2000. The TCFL industry shows some signs of the presence of S-S effects up until 1993. After 1993, the wage ratio and the employment ratio among skilled and unskilled workers in TCFL have started to increase, reducing the possibility of the existence of S-S effects in this industry. However, the sub-sectors of TCFL, clothing & footwear, have experienced the S-S effects over the period 1989 to 2000 as seen from Figure 4.4. Among other manufacturing industries, some have experienced increased relative share of skilled workers along with an increase in the relative wages of skill. These industries include wood & paper product, petroleum, coal, chemical & associated products and other manufacturing. In the remaining industries, such as, printing, publishing, & recorded media, non-metallic mineral products, metal products and machinery & equipment, there has been a drop in the skilled unskilled wage ratios along with an increase in the skilled-unskilled employment ratios. The results of these two groups of industries show no specific existence of S-S effects on Australian labour market. From the results it can be seen that only one out of nine two-digit manufacturing industries shows clear and strong existence of S-S effects on the labour market. Although clothing & footwear industry showed clear evidence of the existence of S-S effects, a more aggregated two-digit industry category, TCFL (which includes textiles and leather together with clothing & footwear) failed to show any evidence of S-S effects at work in the Australian labour market, especially after 1993. Three out of nine two-digit manufacturing industries featured increase in the ratio of skilled to unskilled employment with increased skilled-unskilled wage ratio, which is exactly the opposite of S-S prediction.

Fahrer and Pease (1994) also found no significant decrease in the relative wages in different manufacturing industries except for Australian clothing & footwear industries over the period 1982-83 to 1992-93. They measured the ratio of wages of skilled and unskilled workers taking the wages of business professionals as a proxy for high-skilled wages and wages paid to machine operators of different manufacturing industries as a proxy for low-skilled wages. In their study, they did not analyse the S-S effects with the skilled-unskilled employment ratio along with the skilled-unskilled wage ratios.

Lawrence and Slaughter (1993) found similar results for the U.S. economy regardless of the level of disaggregation of industries (as they used two, three, and four digit industries separately). Lawrence and Slaughter (1993) found that only 10 percent of all industries in U.S. had experienced higher relative wages of skilled workers with a lower ratio of skilled-unskilled employment over the period of 1979 to 1989. Their study showed that at least half of the manufacturing industries in the U.S. experienced rising relative wages of skilled workers along with a rise in relative employment of skilled workers, thereby indicating no strong influence of S-S effects in the U.S. during this period.

Results from the Counterfactual Trade Measurement

To measure the effects of trade for Australia, using a formal method, the effects of increasing import penetration on employment in Australia has been calculated. This method is known as, 'counterfactual measurement of trade', where import penetration (as a percent of final demand) does not increase after the base year[14]. The year 1986 has been used as the base year in this analysis and compared with current year 1996.

The results from the counterfactual trade measurement for Australia have been presented in Table 4.7. The counterfactual trade effect has been measured using 56 manufacturing industries (according to three-digit manufacturing classification used by ABS in input-output analysis). However, the results are arranged and presented according to two-digit ANZSIC of manufacturing industries also used by ABS[15]. The counterfactual measurement refers to the changes in employment in the two digit manufacturing industries due to increased trade. The counterfactual job losses have been measured as the change in 1996 employment compared to 1986 employment due to increased trade over the period, keeping the net imports to final demand ratio fixed at the base year level in these industries.

According to the counterfactual measurement, the increase in trade between 1986 and 1996 has resulted in job losses for both the unskilled and skilled employment in Food, Beverages and Tobacco, Textile, Clothing, Footwear & Leather, Metal Products and Other Manufacturing sectors. The job losses effect is highest on textile, clothing, footwear & leather sector, around 3.5 percent of skilled workers and 22 percent of unskilled workers would lose their jobs due to trade, leaving overall effect on employment in that particular industry of -25.89 percent. Other manufacturing sector had the second largest job losses due to increased trade. According to the calculation, Wood & Paper Product, Printing, Publishing & Recoded Media, Petroleum, Coal, Chemical & Associated Product, Non-Metallic Mineral Product, and Machinery & Equipment sectors have actually gained both in skilled and unskilled employment due to trade over the concerned period. The result, which is similar to the findings of other studies done on different developed countries, states that compared to the effect on skilled workers, increased import penetration caused a relatively larger effect on

[14] This measurement closely follows Sachs and Shatz (1994). The separate effects on skilled and unskilled employment of international trade for all the two-digit manufacturing industries in Australia have been shown here rather than only total employment (skilled plus unskilled) effect.

[15] The results have been presented in two-digit level of industry breakdown as the division of skilled-unskilled employment is available only at two-digit industry level. Calculations are performed at three-digit industry level up to the equation 4.A.8 (in appendix A4.II). Then the percentage change in output, $\Delta Y^{96}/Y^{96}$ has been aggregated (using net imports to final demand of the base year for each industry as weights) to two-digit level and the rest of the calculations have been performed at two-digit level.

unskilled employment in all the sectors. The most affected sectors have been TCFL and other manufacturing. It could be seen from Table 4.6, that the TCFL sector is the relatively more unskilled-intensive sector among all the manufacturing industries.

Table 4.7 Counterfactual Trade Effects on Australian Manufacturing Employment (Percent)

ANZSIC Code	ANZSIC Description	Skilled Employment Effect	Unskilled Employment Effect	Total Employment Effect
21	Food, Beverage & Tobacco	-0.095	-0.413	-0.508
22	Textile, Clothing, Footwear & Leather	-3.545	-22.343	-25.888
23	Wood & Paper Product	4.211	22.641	26.852
24	Printing, Publishing & Recorded Media	0.943	0.943	1.886
25	Petroleum, Coal, Chemical & Associated Product	7.983	14.032	22.015
26	Non-Metallic Mineral Product Manufacturing	1.224	5.128	6.352
27	Metal Product	-2.612	-8.866	-11.478
28	Machinery and Equipment	0.788	1.606	2.394
29	Other Manufacturing	-5.296	-16.921	-21.845

Sources: Author's counterfactual calculations as described in the text and using ABS data (published and unpublished). Details of data have been described in the text.
Note: Denominators are Total Manufacturing employment in the base year 1986.

As imports from developing countries increase along with trade liberalisation, both on the part of Australia and the developing countries, the unskilled workers have been worse affected in all the sectors.

Table 4.8 reports the actual as well as the counterfactual percentage changes in employment separately for skilled, unskilled, and total workers over the period 1986 to 1996. The results show that the counterfactual changes of the skilled worker groups are clearly not correlated with the actual changes of skilled workers in most of the sectors, over the concerned period.

Table 4.8 Actual and Counterfactual Employment Changes by Two-digit Manufacturing Industries, 1986-96

ANZ-	Skilled		Unskilled		Total	
SIC	Actual	Counterfactual	Actual	Counterfactual	Actual	Counterfactual
Code	Change[a]	Change[b]	Change[a]	Change[b]	Change[a]	Change[b]
21	6.480	-0.095	-9.365	-0.413	-2.885	-0.508
22	0.445	-3.545	-30.264	-22.343	-29.819	-25.888
23	13.322	4.211	20.967	22.641	34.288	26.852
24	23.605	0.943	-13.165	0.943	10.439	1.886
25	11.749	7.983	-15.284	14.032	-3.535	22.015
26	6.073	1.224	-16.313	5.128	-10.239	6.352
27	4.427	-2.612	-16.590	-8.866	-12.163	-11.478
28	10.494	0.788	-24.091	1.606	-13.597	2.394
29	11.401	-5.296	-23.033	-16.921	-11.632	-21.845

Source: Author's calculations using ABS data (published and unpublished). Counterfactual measurements of trade effect have been described in appendix A4.II.

a: Actual changes have been measured as the percentage change of the manufacturing employment of skilled and unskilled groups and of total workers for the relevant manufacturing sectors between the period 1986 to 1996.

b: Counterfactual changes have been measured by keeping 1996 trade structure fixed to that of 1986 for skilled, unskilled, and total workers.

As the counterfactual employment changes in the skilled group are negative in some of the sectors and the actual changes in the skilled employment are positive in every sector, it can be concluded that the increased demand for skilled workers are not strongly related to and could not be explained by trade effects in many two-digit manufacturing industries in Australia. The skill changes in wood & paper product, printing, publishing & recorded media, petroleum, coal, chemical & associated product, non-metallic mineral product and machinery & equipment sectors show positive relationships between actual and counterfactual measurements, but the statistical significance of the relationships between these two have been very low. The correlation coefficient among actual and counterfactual skilled employment changes is positive ($r = 0.37$) but not significant. Hence, the actual skilled employment change is not explained by and is not related to trade shifts. The negative relationship between counterfactual skilled and actual skilled employment implies the existence of factors other than the international trade that might have been affecting the Australian labour market.

Table 4.8 also shows that the actual unskilled employment has dropped in all sectors except in wood & paper product industry. The counterfactual changes (drop) of unskilled workers are positively correlated with the actual change of the same type of workers during the period. The correlation coefficient has been calculated as positive (r =0.78) and significant at 5 percent level. The correlation coefficient of the counterfactual and actual changes of total workers is also positive (r = 0.75) and again significant at 5 percent level. From the Table 4.8, it is apparent that the high rates of job losses in the unskilled-labour group in some of the manufacturing sectors, namely, TCFL have been closely related to trade. However, trade could explain the employment growth of unskilled and skilled workers in wood & paper product industries. Also, international trade could not explain the actual increase in employment of skilled workers in four out of nine manufacturing industries. Skilled employment has actually increased in these industries but the trade effects have been found to be negative (decrease in skilled employment due to trade effect) for skilled workers.

The results further reveal that unskilled workers have been worse affected by increased and shifted international trade pattern compared to the skilled workers in Australian manufacturing. However, the increase in international trade over the period 1986 to 1996 cannot explain the increase in total skilled employment or decrease in unskilled employment in different manufacturing sectors. The skilled workers in all the sectors have gained employment and these changes can not be explained by factor content measures of trade effect. This is reflected by the insignificant correlation coefficient of the actual and counterfactual skilled employment changes. In reality, skilled employment in each industry has increased over the period 1986 to 1996. But the counterfactual trade effects reflect that if there were no other effects on the labour market than trade (as is inherently assumed in counterfactual trade effect measurements), then the skilled employment would have decreased in some of the industries. To certain extent, increased international trade can explain the reduced unskilled employment as it shows fall in unskilled employment due to trade effect in most of the sectors. All the results (for skilled, unskilled and total workers) obtained from counterfactual trade measurement indicate that some other factors (such as technological change) along with increased trade are at work behind the labour market movements in Australian manufacturing.

The findings of this study are in line with those other studies done in Australia. For the period 1986-87 to 1993-94, Murtough et al. (1998) found positive net impact of trade on employment in the export-oriented food, beverages & tobacco and basic metal products industries. They found the largest negative impact of trade was on employment in the import competing industries, namely, clothing & footwear and motor vehicles & parts industries. In their study, Fahrer and Pease (1994) showed that among all industries in Australia, only clothing & footwear industry experienced substantial fall in employment due to increased competition from low-wage countries over the period 1981-82 to 1991-92. They employed a numerical method called shift-share analysis, previously used by Krueger (1980) and UNIDO (1986) for other countries, to calculate the contribution of changes in demand, exports, imports, and labour productivity to employment in each industry in Australia over the period 1981-82 to 1991-92. They found that trade accounted for a substantial decline in employment only in clothing & footwear industries that are believed to be the unskilled intensive sectors. Textiles and miscellaneous manufacturing industries suffered a gross job loss from liberalisation in net terms (i.e., after subtracting the effects of domestic demand and exports). They also identified that decline in manufacturing employment due to productivity improvements exceeded the total fall in employment. Thus their findings showed that productivity effects outweighed the trade effects on manufacturing employment. Their results raise concerns about the possible causes behind the improvement in productivity. One plausible and frequently mentioned cause has been the threat of increased competition from imports that leads to productivity improvements (Grossman and Helpman, 1991; Eaton and Kortum, 1996; and Coe, Helpman and Hoffmaister, 1997). This could occur through labour-saving technologies, managerial efficiencies or through competition from trade that drives the least efficient firms out of the market thereby raising the average productivity of the industry.

Sachs and Shatz (1994) estimated the U.S. job loss due to trade over the period 1978-1990 using the same method used in this study. Their results are different from those obtained by Lawrence and Slaughter (1993). Lawrence and Slaughter (1993) found no significant trade effect in U.S. manufacturing. Sachs and Shatz found that trade caused job loss of 7.2 percent of unskilled workers and 2.1 percent of skilled workers over the period 1978 to 1990 in U.S. manufacturing. In more split effects of trade they found that trade from developed countries hardly had any effect on U.S. manufacturing employment. They showed that trade with developed countries actually raised the skilled employment by 2.2 percent and reduced the unskilled employment by only 1.0 percent. Trade with developing countries caused a total decline in employment rate of 5.7 percent. They also identified that the effects of trade with developing countries on skilled and unskilled employments were -4.3 and -6.2 percent, respectively. These results led them to conclude that the impacts of trade with developing countries were negative for both the skilled and unskilled workers in U.S. but the impacts were considerably large on unskilled workers over the period 1978 to 1990.

The factor content measurement of trade effect is not beyond controversy. There are some disagreements among the economists regarding the measurement of factor content of trade and even the appropriateness of the use of this method in finding the effects of international trade with developing countries. Wood (1995) argued that the conventional factor content measurement understates the impact of trade on the unskilled workers. He suggests that rather than using the amount of labour used to produce the imports in the domestic economy (in this case, in the developed country), one should use the amount of labour required to produce the same imports in the developing-country. Using this method his findings are different in magnitude from those of Sachs and Shatz (1994). Wood (1995) found that trade caused 10.8 percent decline in total manufacturing employment measured for all the developed countries. He also showed that trade reduced the unskilled employment by 21.5 percent and increased the skilled employment by 0.3 percent.

In another study, Leamer (1998, 2000) criticised the approach of factor content measurement of trade for calculating the effect of trade on wages. He pointed to the fact that trade and hence the labour content of trade is determined by tastes, technology, factor supplies, and the goods market. In other words, volume of trade is determined endogenously, whereas the prices of the traded goods are determined exogenously and it is improper to relate these two. Also, the factor content is appropriate to use only if the production functions follow a Cobb-Douglas technology, that is, only if these production functions are log linear and if trade is balanced. If these assumptions are invalid then the factor content measurement of trade is of no use.

Krugman (2000) rejects Leamer's claims and argues that if the volume of trade is endogenous then so is price and there should not be any conflict between these two. For the second argument he shows that if there is a small change in factor endowments then there will be a small change expected in prices as well and such a change does not depend on the type of production function. In the third place, Krugman also argues that although a basic assumption of the applicability of the general equilibrium theories of trade is that trade has to be balanced, this assumption does not prevent the economists to use the Computable General Equilibrium (CGE) models. He showed that the conceptual foundation behind the factor content measurement of trade is sound and it should be used until there are some better estimation methods available.

Australian Trade Pattern and Effects on Labour Market

So far the evidences revealed by this study and other studies conducted on Australian economy do not show strong and significant effects of international trade on Australian labour market. The interpretations of the results on wage inequality and trade effects require an analysis of the nature of trade relationships (intra-industry or inter-industry) Australia has with its major trading partners. Even with little evidence of trade effect on Australian labour marker, it would be interesting to see if there is any signal that Australia's increased trade with low-wage countries (which is the trend in Australian trade over last two decades as is shown by the Tables 4.2 and 4.3) would cause distortion in the labour market in future. In view of searching the possible current as well as future effects of trade, the G-L index of intra-industry trade has been measured for eight different three and four-digit Australian manufacturing industries with 52 trading partner countries. Then the equation (4.2) has been estimated.

Table 4.9A and 4.9B present the measured G-L intra-industry trade indexes for the eight Australian manufacturing industries with ten selected (low, medium, and high wage) trading partner countries, for the year 1995. The countries are of different wage levels. From these tables, it can be seen that Australia has high intra-industry trade with New Zealand in five out of eight industries, irrespective of the skill intensity of the industries (for example, G-L index for footwear industry with New Zealand is 0.94). This is due to the Close Economic Relations (CER) agreement between Australia and New Zealand that came into effect in 1983. G-L index of Australia with the high wage countries for the eight industries are mixed. For most of the industries G-L index with U.S. is low. It implies that Australia's trade in these industries with U.S. is more based on comparative advantage than due to economies of scale or product differentiation.

In clothing industry, Australia's G-L indexes with four high-wage countries have been 0, implying complete inter-industry trade, with the exception of only New Zealand. G-L indexes of clothing with low and medium wage countries have also been inter-industry but index numbers have been slightly greater than zeros. This is supported by what have been seen in Table 4.4, which indicates that Australian clothing is heavily export oriented (share of exports in clothing is 1.41 percent of GDP whereas, share of imports is only 0.315 percent of GDP). Altogether, the results state that Australia has comparative advantage in clothing with most of its trading partners, regardless of their income status and trades in clothing have been mainly based on comparative advantage. In chemicals and machineries industries Australia's trade with low and medium wage countries could be categorised as more of intra-industry type, based on the G-L index of these industries with countries like China, Malaysia and South Korea. On the other hand, Australia's trade in footwear industry with low and medium wage countries seems to be completely inter-industry. There is no trade at all with high wage countries in footwear sector, except with New Zealand for which the G-L intra-industry trade index is close to one.

The G-L index of total trade by each country has been presented in the last column of Table 4.9B. It can be seen from these total G-L index that Australia's trade with these high wage and low wage countries at the current industry levels follow the proposition of the new trade theory for the high wage countries. However, G-L indexes have been quite high for the low-wage countries, which is unlike the prediction of the new trade theory.

Table 4.9A: G-L index of Intra-Industry Trade by Industry for Selected Countries for Australia, 1995

Countries	G-L Index of Electronics	G-L Index of Computer	G-L Index of Chemicals	G-L Index of Machineries	G-L Index of Medical & Pharmaceuticals
SITC Codes	76	75	5	71-74	54
Developed Countries					
Germany	0.072	0.581	0.052	0.153	0.010
Japan	0	0.259	0.589	0.087	...
New Zealand	0.719	0	0.638	0.681	0.184
U.K.	0.100	0.571	0.246	0.336	0.400
U.S.	0.099	0.300	0.160	0.160	0.252
Developing Countries					
Brazil	0	0	0.264	0.436	0.640
China	0.284	0	0.698	0.974	0
South Korea	0	0.482	0.737	0.714	...
Malaysia	0.117	0.305	0.961	0.492	0
Thailand	0.299	0.180	0.576	0.686	0

Source: Author's calculations using DFAT (2000b) publication on trade data.

Table 4.9B G-L index of Intra-Industry Trade by Industry for Selected Countries for Australia, 1995

	G-L Index of Clothing	G-L Index of Textiles	G-L Index of Footwear	G-L Index of Total Trade
SITC Codes	84	65	85	
Developed Countries				
Germany	0	0.261	...	0.364
Japan	0	...	...	0.879
New Zealand	0.911	0	0.944	0.852
U.K.	0	0.536	...	0.678
U.S.	0	0.373	...	0.449
Developing Countries				
Brazil	...	0	0	0.808
China	0.341	0	0	0.896
South Korea	0.238	...	0	0.557
Malaysia	0.244	0.849	...	0.823
Thailand	0.545	0.187	0	0.767

Source: Author's calculations using DFAT (2000b) publication on trade data.

The limited evidence of trade effects on Australian labour market may be due to the lack of distinction between the nature of trade (intra-industry and inter-industry) with different countries. To address this point equation (4.2) has been estimated for eight industries (at three and four-digit levels of industry classification breakdown, as described in Section 4.3) in the year 1995, using data for different countries with significant volume of trade (imports and exports) with Australia in those industries. The results of the OLS regressions have been presented in Table 4.10A and Table 4.10B. The former table contains the industries that are relatively more skilled or semi-skilled intensive. The latter table presents the results of industries that are known as unskilled-intensive. The positive coefficient of the variable that states the relative wages of the trading partners to Australian wages, (W_j/W_{Aus}), would imply that low-wage countries have more of inter-industry trade with Australia in that specific industry. Hence, increased trade with low-wage countries in that industry would cause job losses according to the skill intensity in production or would shift wage distribution among workers of different skill levels as predicted by the S-S or factor price equalisation theory. The result would also imply that trade with high wage countries would be intra-industry in nature (i.e., as relative wage of the trading partner increases, Australia's G-L index with that country increases) and that increased trade with high-income countries would not cause any job loss or shifts in wage distribution as predicted by new trade theory, rather it would benefit both the skilled and unskilled workers.

The results in Table 4.10A show that in the high-skill intensive computer & parts industry Australia's trade has been more of inter-industry in nature with low-wage countries. This is indicated by the statistically significant (at 1 per cent level) coefficient of (W_j/W_{Aus}) estimated as 0.201. This is an expected result in the context of the new trade theory. On the other hand, the chemicals industry has a negative and significant (at 1 percent level) coefficient of the relative wage of the partner countries to Australian wage. This result suggests the opposite effect to what have been seen in computers & parts industry. It suggests that Australia's trade in this industry with low-wage countries is intra-industry in nature.

Table 4.10A: Estimated Relationship Between Australia's Trade Pattern and Income Level of Its Trading Partners, OLS Estimates, 1995

Independent Variables	G-L Index of Electronics	G-L Index of Computer	G-L Index of Chemicals	G-L Index of Machineries	G-L Index of Medical & Pharma-ceuticals
	Dependent Variables				
W_j/W_{Aus}	0.044	0.201***	-0.167***	-0.092	0.031
	(0.068)	(0.070)	(0.053)	(0.066)	(0.056)
$\ln(GDP_j*GDP_{Aus})$	0.031	-0.006	0.043*	0.037	0.018
	(0.023)	(0.021)	(0.022)	(0.026)	(0.021)
ln(Distance)	-0.206***	-0.108	-0.101	-0.054	0.019
	(0.071)	(0.095)	(0.092)	(0.088)	(0.040)
Exchange Rate	-0.000002	-0.00004	0.000003*	0.000004*	-0.000004***
	(0.000002)	(0.00007)	(0.000002)	(0.000002)	(0.000002)
$(X_j+M_j)/GDP_{Aus}$	-122.335	11.433	-44.867	-25.026	40.852
	(123.285)	(38.672)	(35.485)	(19.252)	(168.386)
Constant	1.700**	1.158	0.975	0.445	-0.271
	(0.718)	(0.874)	(0.907)	(0.829)	(0.335)
R^2	0.199	0.227	0.160	0.101	0.068
Observations	45	40	49	49	40

*** significant at 1%, ** significant at 5%, * significant at 10%
Robust standard errors have been presented in parentheses.

As Australia's trade with these countries increase, the G-L index of chemicals industry rises and adverse effects on labour market are unlikely to be observed due to increased trade with low-wage countries in this industry. That is, for this industry trade with low-wage countries has been more due to the benefit from expanded market and due to the importance of producing differentiated products within industry rather than due to the advantage of factor endowments. This result is somewhat unexpected in view of what have been learnt from the new trade theory. However, with a closer look at the results may not seem to be that surprising due to the fact that many of the developing (low wage) countries have started to produce semi skill-intensive products. In that case, in some industries, it is sometimes more beneficial for high wage countries like Australia to import some parts of a product from low-wage countries, rather than producing each part at home or import from another high wage country. If this is the case, then trade in these industries with low wage countries may not cause any net job losses in Australia. For all the other industries used in this study, the G-L indexes and the relative wages of the trading partners to Australia's wages do not show any significant (either positive or negative) relationship with each other and hence fails to show any significant effects on Australian labour market.

The results of the unskilled intensive industries presented in Table 4.10B show that the variable W_j/W_{Aus} of the two industries, textiles (321) and clothing (84), do not have any significant effect on G-L index of the respective industries. The coefficient of W_j/W_{Aus} measuring relative wages of trading partner countries is negative for textiles industry and positive for clothing industry, but both these coefficients are insignificant. The footwear (85) industry shows a positive and significant relationship between G-L index and trading partners' income status. This result implies that Australia's trade with low-wage countries in footwear industry is inter-industry and would cause net job losses and income shifts in labour market. This result is highly expected as footwear industry is low-skill intensive and the basis of Australia's trade with low-wage countries in this sector is expected to be comparative advantage. This result also supports the policy of protecting the footwear industry in Australia with high tariff and non-tariff barriers as compared to protection provided to the other industries. The last column of Table 4.10B presents the relationship between G-L index of total trade (for all manufacturing industries) and the relative manufacturing wages of trading partners with wages in Australian manufacturing, controlling for economy size, exchange rate, distance of the trading partners and the scale of openness of Australia with its trading partners. This result also fails to present any significant relationship between relative wages and G-L index and hence, fails to show any significant effect of increased trade with low-wage countries on the shifts in Australian labour market for the year 1995. However, the coefficient is positive and it states that increased total trade with low-wage countries would weakly cause net job-losses or shifts in wage distribution among the skilled and unskilled workers as trade increases with reduced or no protection. It also implies that on average Australia's trade with low-wage countries is mainly based on comparative advantage and not of intra-industry nature

Among the other variables, log product of GDP_j and GDP_{Aus}, has mixed signs (both positive and negative) but significant only for chemicals industry that has a positive coefficient. This result is in accord with what the gravity model postulates. The distance variable has negative coefficients in most industries, which is again expected. This result indicates that the greater is the distance and the transportation costs, the higher is the proportion of trade based on comparative advantage. The exchange rate proves to be an important determinant of both exports and imports and hence, of G-L index. The variable on scale of openness is not significant in any of the industries and is both positive and negative in different industries.

The results presented in Table 4.10A and Table 4.10B indicating the trade effect in Australia, are somewhat expected. This is because the trade involving a developed and a developing country is expected to be more of inter-industry in nature or in other words, based on comparative advantage.

However, these results hold insignificantly in most of the sectors studied. The unexpected results are what we get from the estimated regression equation of textiles industry. Though insignificant, the coefficient of relative wages has negative sign in this industry. The result states that increased trade in this sector with low-wage countries will increase the G-L index and the trade will be more of intra-industry in nature. But in reality, one would expect these sectors in Australia to be largely affected by increased trade with low-wage countries, which is the prediction of S-S theory of trade. Although this result seems unexpected for textiles industry but it is consistent with the G-L intra-industry trade indexes found with different countries from different wage levels (high, medium, or low wage countries).

Table 4.10B Relative Wages of Trading Partners & Australian Trade Pattern of Unskilled Intensive Manufacturing Industries, OLS Estimates, 1995

	Dependent Variables			
Independent Variables	G-L Index of Clothing	G-L Index of Textiles	G-L Index of Footwear	G-L Index of Total Trade
W_j/W_{Aus}	0.133 (0.096)	-0.019 (0.065)	0.418* (0.220)	0.007 (0.074)
$\ln(GDP_j{*}GDP_{Aus})$	-0.064 (0.040)	-0.002 (0.016)	-0.016 (0.011)	0.026 (0.020)
ln(Distance)	-0.093 (0.148)	-0.138 (0.122)	-0.252** (0.101)	-0.161*** (0.041)
Exchange Rate	-0.000001 (0.000002)	-0.000004** (0.000002)	-0.0001* (0.00005)	-0.000003* (0.000002)
$(X_j+M_j)/GDP_{Aus}$	34.709 (42.593)	195.605 (352.204)	256.555 (224.272)	1.519 (3.327)
Constant	1.672 (1.355)	1.480 (1.106)	2.427** (0.952)	1.760 (0.381)
R^2	0.217	0.123	0.685	0.162
Observations	32	44	17	52

*** significant at 1%, ** significant at 5%, * significant at 10%
Robust standard errors are presented in parentheses.

For example, Australia's trade in textiles with Germany, New Zealand, and U.S. (high wage countries) produce G-L indexes of 0.26, 0, and 0.37, respectively. On the other hand, while the G-L indexes for textiles with Brazil, China and India (low-wage countries) are all zero, the indexes for textiles with Malaysia, Philippines and Sri Lanka (medium and low wage countries) are 0.85, 0.99 and 0.65, respectively. Therefore, it is not surprising to find the result (not significant) for textiles industry that implies that Australia's trade with low wage countries will be more of intra-industry in nature. The explanation of this result could be the same as for chemical industries.

From the evidences presented in this section it can be stated that trade with low wage countries, so far, does not pose a great threat to the Australian labour market. If the trade pattern continues to remain same as found in this study, the low-wage countries remain in the low-wage bracket and trade with low-wage countries increase more (as has been the trend for last two decades), then such trade may cause significant net job losses and shifts in wage distribution by skill level in some industries like electronics, clothing and footwear. For the time being, even after distinguishing between intra-industry and inter-industry trade, this study could not find any significant effects on Australian labour market due to increased trade with low wage countries.

These results are similar to the findings of Fahrer and Pease (1994) and Karunaratne (1999). Using different methods, they found mixed evidences for various manufacturing industries in Australia. Their studies also suggest that international trade affects the unskilled intensive sectors significantly but most of the industries fail to show any significant effect of increased trade on overall employment. Studies on U.S. also present mixed evidences of trade effect on the labour market (Lawrence and Slaughter, 1993; Sachs and Shatz, 1994).

4.5 Conclusions

In this chapter, the trade effects on Australian manufacturing industries have been demonstrated. Australian trade with developing countries has grown significantly over the last two decades and has grown sharply since the drastic trade reforms in 1989-90. This study finds significant structural changes in exports and imports after the beginning of sustained reduction of tariff and non-tariff barriers for all manufacturing industries.

Mixed evidence on the presence of S-S effects has been found in Australian manufacturing. The results presented in Figure 4.4, 4.5 and Tables 4.5 and 4.6 indicate that after the trade liberalization, there have been strong S-S effects for some industries, which are primarily unskilled intensive, namely, clothing & footwear, motor vehicles and food, beverages & tobacco. However, for most of the sectors, trade is unable to explain the labour market movements. The counterfactual trade effects show some significant relationship between actual changes in the Australian labour market and the counterfactual changes mainly for the unskilled workers. Counterfactual trade effects on the unskilled workers show some positive correlation with the actual unskilled employment changes over the period 1986 to1996 and the relationship is statistically significant. The counterfactual trade effects could not explain most of the movement of the skilled employment.

The regression of the relative income status of various trading partner countries (low wage or high wage countries) on the Australian trade pattern (measured in terms of G-L index) with those trading partners demonstrate little effect on both the skilled and unskilled intensive sectors, with exceptions of only three sectors. This result proves that so far in most of the manufacturing industries in Australia, increased trade with low-wage countries did not result in any significant net job losses according to the skill intensity of production or shifts in wage distribution among workers of different skill levels. The results also suggest that Australian trade with high wage countries is mostly intra-industry in nature, especially involving high-skill intensive sectors. However, the relationships are insignificant for most of the sectors.

As the regression results of the Australian trade pattern and relative income status of trading partners have shown insignificant and mixed relationships it can be concluded that increased trade with developing countries has posed no significant threat to impoverish the unskilled workers in Australia so far. However, increased trade with low wage countries adversely affects unskilled workers in two of Australia's industries, namely, computer and footwear industries. This is due to the fact that trade in these sectors is heavily inter-industry in nature with the low wage countries (Tables 4.10A and 4.10B). With further decline in protection in future, the effect of trade on Australian manufacturing could be larger than what has been observed in this study.

Australia's trade with developing countries in computer & computer parts industry, which is expected to be highly skilled-labour intensive, is found to be heavily inter-industry in nature. This implies that increased trade with the low wage countries in computer & computer parts industry would cause significant distortions in Australian labour market, whereas, trade with developed or high-income countries would not affect the labour market adversely. Australia's trade in this sector is expected to be more with developed countries than with low-income developing countries as this is a high skill-intensive sector. Other industries, for example, heavy machineries, medicinal & pharmaceutical products industries do not show any significant trade pattern with the countries based on their income status. Intra-industry index for Australian total trade also does not show any significant relationship with the income status of the trading partners even after controlling for distance, exchange rate, economic size and scale of openness with those countries.

However, based on the key findings of this study, it is important to note that there has been little evidence of trade effect on Australian labour market over the last two decades. The results also point to the fact that factors other than trade, e.g., technological change, are likely to be at work behind observed labour market movements in recent years in Australia for most of the sectors. The results cannot rule out the possibility of effects of trade on Australian labour market in view of Australia's increased trade with low-wage countries as well as future trade liberalisations. The results indicate the urgency of continued as well as extended policy attentions with a view to correct the increasing wage inequality and curb rising unemployment among the unskilled workers in Australia.

Chapter Five

Technological Change and Labour Market in Australia

5.1 Introduction

The effect of technological change on the labour market has been one of the most debated issues in recent years. There have been a large number of studies in the U.S. that support the hypothesis that technological change is responsible for the widening of wage differentials by skill level of the workers (Bound and Johnson, 1992; Katz and Murphy, 1992; Juhn, Murphy and Pierce, 1993). Berman, Bound and Griliches (1994) show that despite the increased return to skills, there has been evidence of increased share of non-production workers in U.S. manufacturing. They identified certain relationship between rising share of non-production workers with research and development (R&D) and investments in computers. Berman, Bound and Machin (1998) extended this study for the developed countries and found that skill-biased technological change induced increase in shares of non-production workers. Allen (2001) found that in the U.S., technological change and relative wages of workers with different schooling were largely related with each other over the period 1979 to 1989. In a separate study, Hanson and Harrison (1995) showed that there was no strong evidence of technological change as responsible to widen the gap between skilled and unskilled wages in Mexico in the 1980s.

In recent years, there have been a series of published studies on technological change and demand for skilled employment in Australia. Using one-digit Australia and New Zealand Standard Industry Classification (ANZSIC) level data from ABS, De Laine, Laplagne and Stone (2000, p.49) found that 'the more technology intensive an industry, the more likely it is to have high skilled workers making up a large proportion of its total wage bill or, somewhat less robustly, of its total workforce'. In a multivariate regression model, they used R&D intensity and capital intensity as proxies for the level of technology covering the period of 1978 to 1998. Their study identified the strongest and most consistent evidence of technological change in the manufacturing sector. Using one-digit Australian Standard Industry Classification (ASIC) level data from

1987 to 1994 in a general equilibrium (MONASH simulation) model Laplagne, Marshall and Stone (2001) found results similar to those of De Laine et al., (2000). Laplagne et al., (2001) additionally showed that regardless of the existing relative labour force employed by the industries, technical change bias in the use of skilled workers has been present in Australia. However, both these studies failed to show any significant trade effects on the shifts in the demand for skilled workers in Australia, at the industry as well as macroeconomic levels. In a more recent study, Gretton, Gali and Parham (2002) found that use of information and communication technology (ICT) by firms has significant and positive effect on the productivity growth in eight different industries in Australia. They used firm level data from the Business Longitudinal Survey (BLS) conducted by ABS that covered the period 1994-95 to 1997-98. Their results showed that computer use and Internet access by the firms have positive and significant effects on productivity growth.

The relationship between technological change and labour demand in Australia seems to be somewhat interesting. In Australia, protection provided to different manufacturing industries, including textiles and clothing, fell significantly since late 1980s. After 1989 the overall assistance accorded to manufacturing had been less than 10 percent and by 2001, the rate was reduced to 5 percent. Gretton et al. (2002) found that from late 1970s to 1990s, Information Technology (IT) capital deepening[1] in Australia increased from one-fifth of a percentage point to around one and a quarter percentage points by the latter half of 1990's. They suggested that such IT capital deepening strongly contributed to labour productivity growth in Australia from 1993-94 to 1999-00. Hence, an investigation into the effects of technological change on employment and wages could provide some insights on the broader workings of the Australian labour market. Such an analysis seems highly relevant for the latter half of 1990's, a period marked by trade liberalisation and IT capital deepening strategies adopted by Australian firms.

Despite the growing concerns that technological change may affect the labour force and job conditions in a variety of ways, very little attention has been paid to find the magnitude of such effects. More importantly, these issues have rarely been examined from a microeconomic perspective. In view of this dearth in literature, this chapter

[1] Gretton et al. (2002) measured capital deepening as the income share multiplied by the growth in the IT-labour ratio.

purports to examine the effect of various technological indicators on Australian labour market using firm level longitudinal data over the period 1995-96 to 1997-98. The chapter explores the variation of technological change effects on wages and employment across and within different industries in Australia. Also, technological change effects on firm specific skilled-unskilled employment ratio have been analysed.

Existing literature in technological change effects on labour market involves some traditional technology indicators, e.g., R&D share, capital intensity etc. The empirical approach adopted in this chapter encompasses a wide range of indicators of technological change, such as, R&D expenditure relative to total sales by firms (R&DIntens), major increases in the use of accounting software (AcctSoft), major increase in other administrative computer systems (AdmComp) and major increase in production technology (ProdTech), expectation of introduction of any new goods and services (Intgood) and any new innovation in goods and services (NewInv). The technological change indicators also include four variables on computer use by firms, for 1996-97 only. Thus, this study furthers the concept of technological change that affects the labour market by incorporating various indicators of technological change rather than considering only the traditional indicators such as R&D intensity and computer use.

Also, most of the studies done on technological change effects on the labour market (e.g., Berman, Bound and Griliches, 1994; De Laine et al., 2000; Allen, 2001) do not incorporate trade liberalisation and labour institutions as the explanatory factors. To address this issue, this chapter includes export intensity and unionisation as factors determining labour market movements together with different technological indicators. This should be viewed as an important extension in view of significant changes in the structure and processes in industrial relations arrangements in Australia during 1990s and significant decline in protections (tariff and non-tariff) given to Australian producers since 1989-90 (Productivity Commission, 2000).

This chapter is expected to contribute to the existing literature by examining how the measures of technological change relate to changes in the wages paid by the firms and employment within and across sectors after controlling for trade, labour institutions, and product demand. Despite the traditional concerns that technological change can affect the relative skilled-unskilled wages and employment, the question of how technology has been affecting the unskilled workers in terms of their employment, has not received much attention. In other words, the existing literature on the effects of technological change focused on the technological change as skilled biased only if the technological change is found to be widening the gap between the skilled and unskilled wages. These studies overlook one aspect of the technological change, that is, the skill-biased technological change could make both the skilled workers better off in terms of wages (and not necessarily in terms of skilled employment) without affecting the unskilled employment. This type of technological change is termed as intensive skill-biased technological change (Johnson and Stafford, 1999). When the technological change is extensive skill-biased the unskilled workers would be affected both in terms of wages and employment. Keeping this weakness of the existing literature in mind, this chapter investigates whether technological change experienced by any sector have been intensive or extensive skilled-biased.

The chapter is organized in the following manner. Section 5.2 provides the theoretical frameworks on issues of skill-biased technological change and labour market in an open economy. Section 5.3 describes the data and empirical models. Results and interpretations have been presented in section 5.4. Section 5.5 summarises the findings and concludes.

The results of the study indicate that there is significant effect of skill-biased technological change on the Australian labour market over the period 1995-96 to 1997-98. Among the technological change variables, share of R&D expenditure on total sales (R&DIntens) has been found to be a powerful explanatory factor of labour market movements in many sectors. The effects of other technological change indicators, openness, and labour institutions have been found to be different in signs and in magnitude for various sectors depending on the sector specific skill intensity, export orientation, age of firms and union power. It is interesting to note that, among the technological change indicators, R&D intensity fails to provide any significant indication of affecting the unskilled employment. Other technological change variables have some significant impacts on the unskilled employment of firms in various sectors. While including different computer use variables for only 1996-97, the results from OLS regressions show that the technological change via the variable *CompR* that measures relative computer use by employees in the firms, poses some negative effects on the average employment and wages as well as on unskilled employment. In other words, technological change via *CompR* has been more of extensive skill-biased in nature, having negative effects on employment (and affecting mostly the unskilled workers) of Australian small and medium size firms in sectors like manufacturing, wholesale trade etc. Computer use variables mostly caused extensive skill-biased technological change in different sectors and thus, reduced the relative unskilled employment.

The effects of all technological change variables together (except the R&D intensity and R&D dummy) in Random Effect panel regression model seem to have caused significant reduction in relative unskilled employment in combined sector. This result suggests that technological change via increased use of advanced products or services in all the firms in Australia have been extensive skill-biased in nature.

The results provide evidence of technological change affecting Australian labour market. However, this does not mean that technology is the only factor that could distort the labour market. In fact, the full effect of technological change on labour market structure cannot be captured without closing the model by looking at supply side effects (e.g., education level, gender or experience of the employees etc.), which is beyond the scope of this study.

5.2 Theoretical Framework

Skill-Biased Technological Change: Within and Between Industry Decompositions

Increased employment of skilled workers in the production process can be explained by increase in international trade, sector-biased technological change, or skill-biased technological change. Increased international trade and sector-biased technological change would shift the employment towards skilled workers by shifting the labour demand *between* industries, from the unskilled-intensive industries to those intensive in skilled workers. On the other hand, skill-biased technological change would shift the skill composition of labour demand *within* industries. To measure the existence of skill-biased technological change and its effects on shifts in skill demand in any economy, the familiar method is to break down the overall shift of skilled employment into its components. One of the components is the measure of skill improvement due to increased investment in R&D and innovations. In this case, the shift would be the change in labour demand *within* the industries that use skilled workers relatively intensively. The other component is the measure of the shifts in skilled-labour demand due to the shift in product demand, caused by some other factors such as increased international trade or sector-bias of technological change. This component represents the shift in labour demand *between* industries. The *within* industries shift of skills is the prerequisite for explaining rising wage inequality due to skill-biased technological change (Berman, Bound, and Griliches, 1994).

Berman and Machin (2000) present the breakdown of the overall shifts in the skilled demand into components that measure the extent of skill upgrading taking place *within* industries and *between* industries. From the measurement of economy wide *within* and *between* industry components in shift in skill demand in 12 developed countries, they clarified that the bulk of the skill upgrading occurred *within*, and not *between* industries. More research on identifying the industries that have had faster growth rates in upgrading skills and the industry characteristics would shed light on the factors that are behind the improvement of the skilled labour demand.

Another test of technological change affecting the labour market could be based on the prediction that employment and wages are correlated with technology indicators such as, innovation, increased R&D, computer use, access to the Internet etc. The theoretical underpinnings of the labour market distortions and technological change have been briefly discussed below.

Labour Market and Technological Change in an Open Economy

To observe the effect of the biased technological change in an open economy, the common approach in the literature is to use a Cobb-Douglas production function[2]. Let us assume that there are three industries, skill-intensive M, unskilled-intensive P (both of the products are traded internationally), and non-traded service sector K. In the

[2] The discussion presented in this section is based on Johnson and Stafford (1999).

production process, two inputs are used – skilled (S) and unskilled (U) labour. The Cobb-Douglas production function is then specified as:

$$Y_i = A_i (\delta_i S_i)^{\alpha_i} U_i^{1-\alpha_i} \qquad i = M, P \text{ and } K \qquad (5.1)$$

where A_i is the neutral technological parameter, δ_i represents the efficiency of the skilled workers per unit of S_i, Y is Output and α and $(1-\alpha)$ stand for the shares of skilled and unskilled workers, respectively.

There could be three different types of technological change, for example, neutral technological change (indicated by changes in A_i), *intensive* skill-biased technological change (implying that efficiency of skilled-labour goes up, i.e., δ_i increases) and an *extensive* skill-biased technological change (meaning that skilled workers can perform some of the works previously done by unskilled workers, i.e., α_i rises). The effects of extensive skill-biased technological change on the employment would be to reduce the relative use of unskilled workers. In other words, there would be shifts in demand toward skilled workers from unskilled workers. However, the impact of intensive skill-biased technological change on employment may not reduce the unskilled employment.

The total percentage change of technology in the production function Y_i, at any given level of inputs (S and U constant) can be captured as follows by totally differentiating (5.1) with respect to *time* and making the changes through *time* proportional[3] and then with some rearrangements

$$\gamma_i = \hat{A}_i + \alpha_i \hat{\delta}_i + \ln\left(\frac{\delta_i S_i}{U_i}\right) d\alpha_i \qquad (5.1.1)$$

where, $\gamma_i \geq 0$, that is, technological change is always positive or 0, as no firm would use the technology that have higher costs of production. ^ represents the percentage change through time and the other terms have the same meaning as in 5.1.

[3] For details see Johnson and Stafford (1999).

In an open economy the effects of different types of technological change on the relative factor prices (in this case relative wages, W_S/W_U) (holding P_M/P_P constant) would be[4]:

$$\frac{\hat{W}_S}{\hat{W}_U}=\frac{\gamma_M-\gamma_P}{\alpha_M-\alpha_P}=\frac{\left(\hat{A}_M-\hat{A}_P\right)+\left(\alpha_M\hat{\delta}_M-\alpha_P\hat{\delta}_P\right)+\ln\left(\frac{\delta_M S_M}{U_M}\right)d\alpha_M-\ln\left(\frac{\delta_P S_P}{U_P}\right)d\alpha_P}{\alpha_M-\alpha_P} \quad (5.2)$$

The prices P_M and P_P are exogenously determined as these are the traded product prices and the economy is a small open economy compared to the rest of the world and hence, is unable to affect the prices of the traded products (assuming that there is no trade barrier, no transaction costs etc.). The price of the non-traded service sector is endogenous in this model.

If technological change is intensive skill biased, then the effect on relative wage would depend on the sector in which the change has occurred (unskilled or skill intensive, i.e., if there is an increase in δ_M or δ_P). When the technological change occurs in skill-intensive traded sector then it would increase the skilled-unskilled wage ratio. On the other hand, technological change in unskilled intensive traded sector would reduce the gap between skilled and unskilled wages. The technological change in non-traded sector (represented by an increase in δ_K) would have no effect on relative wages.

If extensive skill-biased technological change is recorded (i.e., α_i increases), the effects of such technological change would again depend on the sector bias of technological change. If the extensive skill-biased technological change takes place in skill intensive sector then the relative wages of skilled workers would increase. If skill-biased technological change occurs in unskilled-intensive sector then wage inequality would

[4] Wage determination can be seen clearly from a zero profit condition: $P_iY_i - W_SS_i - W_UU_i = 0$ (5.3). Taking logarithmic derivatives of the three zero profit conditions of the three industries, we get the proportional changes in the wage rates:

$$\hat{P}_M+\gamma_M=\alpha_M\hat{W}_S+\left(1-\alpha_M\right)\hat{W}_U \quad (5.3.1)$$

$$\hat{P}_P+\gamma_P=\alpha_P\hat{W}_S+\left(1-\alpha_P\right)\hat{W}_U \quad (5.3.2)$$

and

$$\hat{P}_K+\gamma_K=\alpha_K\hat{W}_S+\left(1-\alpha_K\right)\hat{W}_U \quad (5.3.3)$$

decline and if the skill-biased technological change is recorded in the non-traded service sector then the relative wages would not change at all.

One aspect of technological advancement comes through innovations of new technologies that can be regarded as embodied in physical and human capital. These types of technological advancement can be tracked through models with an expanding variety of products introduced by Romer (1986,1990) and discussed in Barro and Sala-i-Martin (1995, ch.6). In a recent study in Australia, Gretton et al. (2002) used a similar analytical framework based on a Cobb-Douglas function to estimate ICT effects and impacts on labour productivity in Australia. Drawing on the idea of Gretton et al. (2002), a simple model that leads to testable predictions on the relationship between employment, real wages and technological change as well as openness has been outlined in this section.

Standard microeconomic theories suggest that rational producers would use factor inputs (labour and capital) in such a mix that minimises their costs. Hence, the optimum labour demand could be obtained (applying Shepard's Lemma) from a firm's cost function. Following Hamermesh (1993), a CES cost function has been considered in this study. This cost function, aligned with the above-mentioned theoretical framework can be written as follows:

$$C = AY\left(\alpha^{\sigma} w^{1-\sigma} + (1-\alpha)^{\sigma} r^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{5.4}$$

where, Y is output, A represents the technological change through different inputs embodied in capital and labour that would have impact on costs, w is the real wage rate, r is the rate of return to capital, α is the parameter and ranges between 0 to 1. $\sigma = 1/(1-\rho) \geq 0$, which is the elasticity of substitution and ρ is a parameter where, $1 \geq \rho \geq -\infty$. If ρ tends to 0, σ tends to 1 and the production function[5] becomes Cobb-Douglas. If ρ is equal to 1 then σ tends to∞. In this case, the factor inputs, labour (L) and capital (K), are perfect substitutes of each other. If ρ tends to -∞ then σ tends to 0. In this case the underlying production function becomes Leontief function and the inputs are not substitutable at all. These are the special cases of CES.

[5] The underlying linear homogeneous production function is: $Y = \left[\alpha L^{\rho} + (1-\alpha)K^{\rho}\right]^{1/\rho}$

Applying Shepard's Lemma, the following demand for labour from the cost function (5.4) has been obtained

$$L = \frac{\delta C}{\delta w} = \alpha^{\sigma} w^{-\sigma} YA \qquad (5.5)$$

Taking logarithms in (5.5) yields the following estimable regression specification

$$\ln L = \alpha'' - \sigma \ln w + \ln Y + \ln A \qquad (5.6)$$

where α'' is a constant.

The demand for labour increases with output Y and decreases with wage, w. Various inputs containing the technological change, except capital, may have different impacts on the employment of firms, both in magnitude and signs. It is not possible to treat wages paid by the firms as exogenous. Wages paid by the firms is actually endogenous, which is a dependent variable in the wage equation. To resolve the problem of endogeneity of the wage variable a joint estimation of the employment and wage equation can be performed (Revenga, 1995). Simple unconstrained estimates can also be obtained by estimating the two equations separately (Berman, Bound and Griliches, 1994; Rama, 1994, Revenga, 1995). Wages paid by different firms are then assumed to move together over time, in response to macroeconomic shocks (De Laine et al. 2000). A wage equation of the same type can be summarised from the above model for estimation (Rama, 1994; De Laine et al. 2000).

In this study, a cost function of CES specification has been preferred to a translog specification due to few reasons. CES function is simple and has been widely used for estimations. It has relatively few parameters and restricts substitution elasticities to be constant (Fallon and Layard, 1975; Krusell, Ohanion, Ríos-Rull, Violante, 2000). On the other hand, translog function has much higher number of parameters. This would reduce the degrees of freedom causing an estimation problem, especially for some sectors included in this study, which have small samples. Also, in the translog functions, substitution elasticities vary over time, which would complicate the explanations of the effects of technological change on the labour market.

5.3 Empirical Models and Data Description

Empirical Specification

Within and Between Industry Decompositions

Based on the discussion presented in section 5.2, *within* and *between* industries decompositions of skill-biased technological change could be examined by taking a composite change of skill upgrading *within* industries and *between* industries. Hence, the following decomposition method for aggregate changes in employment shares of the skilled workers in two-digit manufacturing industries in Australia has been used

$$\Delta S = \sum_i \Delta S_i \overline{P_i} + \sum_i \Delta P_i \overline{S_i} \qquad (5.7)$$

where i (i=1 ....9) is the number of manufacturing industries. S_i is the share of skilled to total employment in industry *i,* and P_i is the share of employment of the *i*-th industry. A bar indicates time mean. The first term of the equation (5.7) is the measure of increased skilled demand and is derived from the increased use of skilled-labour *within* an industry. The second term is the shift in skilled demand due to reallocation of workers from low to high skill-intensive industries. In other words, the second term indicates that the shift in labour demand occurred *between* industries. The decomposition of shifts in skill demand into *within* and *between* industry components is crucial as the extent of concentration of the shifts in any specific industry would reveal the importance of different explanations about the observed shifts in the skill demand.

If the decomposition of *within* and *between* industry change in skilled labour demand shows that there is evidence of *within* industry skill demand movements then it would be worthwhile to investigate the effects of different technological change indicators on the labour market in Australia.

Empirical Specification of Technological Change Effects

Assuming that the impact of technology can be approximated by a linear function, the labour demand model presented earlier in Section 5.2, using a CES cost function, can be summarised in the following equations

$$lnEmpl_{it} = \alpha + \beta_0 lnWage_{it} + \beta_1 lnSales_{it} + \beta_2\, ExpShare_{it} + \beta_3\, R\&DIntens_{it} + \beta_4\, Union_{it} + \beta_5\, Age_{it} + \beta_6\, R\&D_{it} + \beta_7\, NewInv_{it} + \beta_8\, AcctSoft._{it} + \beta_9\, AdmComp_{it} + \beta_{10}\, ProdTech_{it} + \varepsilon_{it} \quad (5.8)$$

$$lnWage_{it} = \theta + \gamma_0 ln(Empl)_{it} + \gamma_1 ln(Sales)_{it} + \gamma_2\, ExpShare_{it} + \gamma_3\, R\&DIntens_{it} + \gamma_4\, Union_{it} + \gamma_5\, Age_{it} + \gamma_6\, R\&D_{it} + \gamma_7\, NewInv_{it} + \gamma_8\, AcctSoft._{it} + \gamma_9\, AdmComp_{it} + \gamma_{10}\, ProdTech_{it} + v_{it} \quad (5.9)$$

Together with the employment and wage equations, to examine the determinants of skilled-unskilled employment ratio skilled/unskilled employment ratio equations have been estimated for each sector following Hanson and Harrison (1995). The equation is written as follows

$$Sk/Unsk_{it} = \alpha + \lambda_0 Sk/UnskWage_{it} + \lambda_1 lnSales_{it} + \lambda_2\, ExpShare_{it} + \lambda_3\, R\&DIntens_{it} + \lambda_4\, Union_{it} + \lambda_5\, Age_{it} + \lambda_6\, R\&D_{it} + \lambda_7\, NewInv_{it} + \lambda_8\, AcctSoft._{it} + \lambda_9\, AdmComp_{it} + \lambda_{10} ProdTech_{it} + u_{it} \quad (5.10)$$

In this model wages and relative wages have been included as explanatory variables in the employment equation and skilled-unskilled employment ratio equations, respectively. But as discussed in Section 5.2, wages are actually endogenous[6]. Based on the discussion in Section 5.2 and following De Laine et al. (2000), Berman et al., (1994), Rama (1994) and Revenga (1995) the wages can be dropped assuming wages paid by different firms move together over time, in response to macroeconomic shocks. But one of the central problems addressed in this study is that the relative wages of skilled and unskilled workers have been changing over time. Hence, to proxy for the influence of wages and relative wages on employment and on skilled-unskilled employment ratio, after dropping wages from equation (5.8) and (5.10), time dummies

[6] However it should be noted that the endogeneity problem of wages is not as big as for industry data or even data on large firms as these are all small to medium sized firms. Hence, it is not unreasonable to model the firms as price takers in the input markets.

have been included in the empirical specification of employment and employment ratio equations. Since the wages are functions of technological change variables (this can be assumed based on the whole debate of rising wage inequality and technological change discussed in the thesis) technological change indicators are also assumed to capture the effects of wages and relative wages in employment and employment ratio equations.

Hence, after dropping wages from the employment equation and including the time dummies in equation (5.8) the estimable employment equation becomes

$$\begin{aligned}\ln Empl_{it} &= \alpha' + \beta_1' \ln Sales_{it} + \beta_2' ExpShare_{it} + \beta_3' R\&DIntens_{it} + \beta_4' Union_{it} \\ &+ \beta_5' Age_{it} + \beta_6' R\&D_{it} + \beta_7' NewInv_{it} + \beta_8' AcctSoft_{it} + \beta_9' AdmComp_{it} \\ &+ \beta_{10}' \Pr odTech_{it} + \beta_{11}' TimeD97_{it} + \beta_{12}' TimeD98_{it} + \varepsilon_{it}'\end{aligned} \tag{5.8'}$$

Then the empirical model of the wage equation for estimation can be summarised as follows:

$$\begin{aligned}\ln Wage_{it} &= \theta' + \gamma_1' \ln Sales_{it} + \gamma_2' ExpShare_{it} + \gamma_3' R\&DIntens_{it} + \gamma_4' Union_{it} \\ &+ \gamma_5' Age_{it} + \gamma_6' R\&D_{it} + \gamma_7' NewInv_{it} + \gamma_8' AcctSoft_{it} + \gamma_9' AdmComp_{it} \\ &+ \gamma_{10}' \Pr odTech_{it} + \gamma_{11}' TimeD97_{it} + \gamma_{12}' TimeD98_{it} + \upsilon_{it}'\end{aligned} \tag{5.9'}$$

Similarly, the estimable form of the skilled-unskilled employment ratio equation becomes

$$\begin{aligned}Sk/Unsk_{it} &= \alpha'' + \lambda_1' \ln Sales_{it} + \lambda_2' ExpShare_{it} + \lambda_3' R\&DIntens_{it} + \lambda_4' Union_{it} \\ &+ \lambda_5' Age_{it} + \lambda_6' R\&D_{it} + \lambda_7' NewInv_{it} + \lambda_8' AcctSoft_{it} + \lambda_9' AdmComp_{it} \\ &+ \lambda_{10}' \Pr odTech_{it} + \lambda_{11}' TimeD97_{it} + \lambda_{12}' TimeD98_{it} + \varepsilon_{it}''\end{aligned} \tag{5.10'}$$

where, the subscript *i* stands for the firm and *t* is the time period (t = 1,2 ,3). $Empl_{it}$ stands for the total number of employment in firm *i* and $Wage_{it}$ represents the real wage paid by the firm *i* and $Sk/Unsk_{it}$ represents the skilled and unskilled employment in firm i. $Sales_{it}$ indicates the real sales of *i*-th firm, $RDIntens_{it}$ shows the share of R&D expenditure in total sales of *i*-th firm at time *t* and $ExpShare_{it}$ represents the share of exports in total sales. Unfortunately, there is no information on imports or use of imported materials by the firms in the BLS data. All the current price values of variables have been expressed in real terms[7]. The variables $Union_{it}$ and Age_{it} indicate the percent of employees who are members of trade union in each firm and the age of the firm *i*, respectively[8]. All the other variables are dummy variables on technological change.

The employment and wage equations have been estimated using Random Effects panel regression model. The statistical tests for choosing the random effects over fixed effects have been performed to support the choice of random effects panel estimators. The test statistics, Hausman specification tests and Breusch-Pagan Lagrange multiplier tests, have been presented in Table 5.5[9].

Some other indicators of technological change affecting wage and employment of the firms have also been included in this study. Among these an important indicator is whether the businesses performed or paid others to perform R&D (R&D), and this has been used as a dummy variable. *R&D* is an input measure of technological change. Information on the introduction of new and improved product or services, ($NewInv_{it}$), has been included in the equations as a dummy variable. The rationale behind using innovation information is that, innovation shows research output and not input, thereby capturing some of the technological change effects on the labour market. Haskel and Slaughter (2001) successfully pointed out the importance of innovation as a factor determining technological change.

Allen (2001) mentions that technological change can be captured from the effects of the introduction of new equipments. Hence, the introduction or increased use of accounting softwares (AcctSoft), other administrative computer systems (AdmComp), and production/services technology (ProdTech) compared to the previous year can be indicative of technological change and may have effect on the wages, employment, and ratio of skilled-unskilled workers in various firms. Therefore, these three more dummy variables, which are believed to be indicators of technological change, have been included in the regression analyses.

[7] Details of the indexes used to transform the variables in real terms have been given in the appendix A5.II.
[8] Details of the variables have been given in the appendix A5.II.
[9] Brief discussions on the choice of random effects and on the tests have been provided in appendix A5.III.

The expected effects and signs of these technology variables on employment and wages are ambiguous. If the technological change is intensive skill-biased and occurs in skill-intensive or non-traded sectors, then the employment may not be affected or may show positive response. If technological change occurs in unskilled intensive sectors then the effects on employment would be ambiguous. On the other hand, if the technological change is extensive skill-biased then the effects on employment are expected to be negative. This would be so because as the skilled workers perform some of the jobs previously done by unskilled workers, demand for unskilled workers falls. This in turn, would change the skill mix and may result in a fall in the total employment. At the end, whether there would be a positive or negative effect on employment would depend on the offsetting power of the increased productivity of skilled workers and on the ease of substitutability between skilled and unskilled workers. Hence, the effects of technological change on employment would be ambiguous. The effects of skill-biased technological change on average wages and hence on the costs of firms are ambiguous. Haskel and Slaughter (2001) describes the effects of intensive and extensive skill-biased technological change on costs of firms. They mention that if the technological change is intensive skill-biased (raises the productivity of the skilled) then it reduces the costs. But if it both raises the productivity of skilled and lowers the productivity of unskilled (extensive skill-biased technological change) then it can lower, leave unchanged or even raise costs. The effects of intensive or extensive skill-biased technological change on relative wages could be predicted. Due to data unavailability, effects of technological change on skilled-unskilled wage ratio could not be estimated in this study. The types of technological change have been identified mainly by investigating their effects on employment together with their effects on skilled-unskilled employment ratios.

When the technological change reduces the average employment of firms in a sector, this could be either due to a reduction in skilled or unskilled or both skilled and unskilled employment. Hence, whether the technological change is intensive or extensive skill-biased cannot be determined only from the employment equation results. However, looking at the results from the skilled-unskilled employment ratio together with the employment and wage equation results of the same sector, the type of technological change, and its effects on skilled or unskilled employment can be determined. For example, if the coefficient of the same technological change variable (which has a negative effect on employment and positive or negative effect on wages) is positive in the skilled-unskilled employment ratio equation, then it implies an increase in the relative skilled employment even when the average employment by the firm in that sector has dropped. In this case, the technological change would be extensive skill-biased causing decline in relative unskilled employment as well as total employment (indicated by the negative coefficient in the employment equation) of firms in that sector. If the coefficient of the technological change variable in skilled-unskilled employment ratio is negative implying a drop in relative skilled employment and its effect on wages is negative, then there would be no negative effect of technological change on unskilled employment. Here only the productivity of the skilled workers increased requiring less skilled workers in the production process that reduces the skilled-unskilled employment ratio and average wages. In this case, the technological change is intensive skill-biased. On the other hand, if the coefficient of the technological change variable is positive in the employment and wage equation and also in the skilled-unskilled employment ratio equation, then the technological change would be extensive skill-biased. In this case, increase in the skilled employment would offset the decrease in the unskilled employment keeping a positive effect on total employment and wages. If the technological change variable has a positive coefficient in employment and wage equation but negative coefficient in skilled-unskilled employment ratio then it implies weak intensive skill-biased technological change effects on unskilled employment, which actually raised the relative unskilled employment and the average wages paid by firms in that specific sector. These analyses will be valid even if the technological change variable has a significant effect on employment and wages but not on the skilled-unskilled employment ratio. Only in that case, the intensive or extensive skill-biased technological changes will be weakly supported by available evidences.

One simple table can be used to present the above discussion on analysing the results from employment, wage, and skilled-unskilled employment ratio equations. Table 5.0 below summarises the above discussion.

Table 5.0 Determination of Intensive and Extensive Skill-Biased Technological Change

	Equations			Type of Skill-Biased Technological Change	
	Employ-ment	Wages	Employ-ment Ratio	Intensive	Extensive
Estimated Effects of Technological Change Variables	+	-	-	×	
	+	±	+		×
	-	-	-	×	
	-	±	+		×

It can be seen from the above table that the conclusions on whether technological change is in itself extensive skill-biased can be determined solely from the estimated signs of the skilled-unskilled employment ratio equations. For the evidence of strong intensive skill-biased technological change the effects of the technological change variable on wages[10] and on skilled-unskilled employment ratio has to be negative. To determine the effect of skill-biased technological change on overall labour demand it is better to combine the results from employment and wage equations with skilled-unskilled employment ratio equation.

Union density is one of the structural forces that affect labour market patterns as well as technological change (Rama, 1994; Haskel and Slaughter, 2001). To control for union effects as a structural force or as a source to affect technological change, the percentage union density in each firm, ($Union_{it}$), has been incorporated in this study. The impact of declining union strength on the employment and wages are expected to be ambiguous. Declining union density affects the employment and wage decisions of the firms by reducing the restraints from the workers to introduce advanced technology. It also induces the workers to learn and adjust to new work practices. The end result is increased productivity, increased wages for the skilled and increased or decreased average wage rate. The effect on employment could also be positive or negative depending on whether the relative number of skilled workers rises due to decreased union density and whether the number of unskilled workers remains same or some unskilled workers get laid off. There are numerous works that try to establish the

[10] As Haskel and Slaughter (2001) pointed out that if skill-biased technological change is intensive in nature then it reduces the costs. But if it is extensive skill-biased then (raised the productivity of skilled and lowers the productivity of unskilled) then it can lower, leave unchanged, or even raise costs.

relationship between declining role of labour market institutions and wage structure. Card (1991), Freeman (1993), Lemieux (1993), found that in the U.S. declining unionisation had considerable impact on the wage structure. Gosling and Machin (1995) also found similar effect of unionization on wage structure for the U.K. economy. In general, wage structure experiences higher distortions in countries where labour market institutions play a reduced role.

The variable R&D intensity is probably endogenous (Machin and Van Reenen, 1998) and so is union density. In the existing literature (e.g., Allen, 2001; Miller, Mulvey and Neo, 1999), as well as in this study, R&D intensity and union density have been considered exogenous. Taking R & D intensity as an endogenous variable, Machin et al, (1998) examined the effect of R&D intensity, for five different developed countries and found that the estimated coefficients were not significantly different from those obtained assuming R&D as exogenous and that the overall results remained robust.

To control for the effects of increased openness on the labour market, exports as a share of total sales, ($ExpShare_{it}$), has been used as an explanatory variable. Changes in trade policy could indirectly affect the demand for skilled labour by providing a country the opportunity to raise its exports. If the export intensive sectors demand more skilled workers driving the wages of skilled workers up then the firms may substitute unskilled for skilled workers. The firms in export intensive sector may also demand more skills as they use more advanced technology or different product mix than before. This could explain some of the movements in the labour market (Hanson et al., 1995). Hence, the effect of *ExpShare* on labour demand would be ambiguous and following the same reasoning, effects of *ExpShare* on wages would be ambiguous as well. The export-oriented sectors are expected to have a negative relationship between export share and skilled-unskilled employment ratio. In the other sectors, relationship between export share and skilled-unskilled employment ratio would be ambiguous or insignificant.

Age of the firms is an important determinant of firms' growth, survival as well as the variability of firm growth. As a result, age of the firm, Age_{it}, has been included as an explanatory variable in the regression equations (5.8), (5.9), and (5.10). Previous studies found that growth of firms declines with higher age of the firms (as the firms get older) (Evans, 1987; Doms, Dunne and Roberts, 1995; Gretton et al., 2002). However, the effect of Age_{it} on employment and skilled-unskilled employment ratio would be ambiguous.

The BLS data provide information on computer use by the firms for the year 1996-97 only. Hence, equations (5.8'), (5.9'), and (5.10') have been estimated using OLS incorporating some additional variables on computer usage. These regressions have been run for only 1996-97, as the computer usage variables are available from the BLS database for this year only. There are no time dummies in these regressions. The technological change variables have been used as proxy for wages in the employment and employment ratio equations as the data is for year 1997 only. The information available regarding computer use by the firms include whether the firm uses computers ($ComBus_i$), the length of computer use by the firm ($ComLong_i$), and whether the firm has access to Internet ($NetAcc_i$). All these three are dummy variables. The other variable included in the model is the ratio of the employees that use the computer to total employees in a firm, ($CompR_i$).[11] The use of computers, as well as, the access to network in the production and marketing process increases the efficiency of the firms. The signs of the estimated coefficients of these technology indicators on wages, employment, as well as skilled-unskilled employment ratio would be ambiguous like other technology indicators. Taking into consideration of the use of computers by firms to examine the effect of technological change on labour market has not been a new concept. Using micro level data, Krueger (1993) found that during early 1980s, in the U.S., the workers who used computers at workplace earned more than those who did not. Card, Kramarz and Lemieux (1996) also found evidence of the effects of computer use on the wage growth of both men and women in the U.S. In Australia, Gretton et al. (2002) identified a positive relation between the computer use and productivity growth in all the sectors.

Data Description

The data used in empirical analysis have been drawn from the firm level Business Growth and Performance Survey, also known as the Australian Business Longitudinal Survey (BLS). The sample covers the period 1994-95 to 1997-98. Out of the 9732 business units included in the original survey, around 5 thousand units have been used

[11] These variable definitions have been included in appendix A5.II, Table 5.A2.

in this study[12] covering the period from 1995-96 to 1997-98. The year 1994-95 was not included as some of the crucial explanatory variables used in this analysis are not available for this year. Using the data for these three years, the effects of technological change on employment and wages of firms have been examined in various industries namely, Mining, Manufacturing, Construction, Wholesale Trade, Retail Trade, Accommodations, Cafes & Restaurants, Transport & Storage, Finance & Insurance, Property & Business, Cultural & Recreational, and Personal & Other Services as well as for all sectors combined.

When the BLS data have been extensively used in this study, there are some weaknesses of BLS data that may affect the results stemming from it. First, the BLS data over-samples from innovative and exporting firms. Hence, it may not represent average firms of small and medium size in Australia. Second, two potential problems have been raised by previous users. One problem mentioned by Will and Wilson (2001) and that is, there may be problems in calculating the age of firms. The other problem is mentioned by Tseng and Wooden (2001). They pointed to the fact that the firms without employees should better be omitted. In this study, the firms without employees have also been dropped. Tseng and Wooden also omitted the firms for which data have been imputed for some years.

The variable $lnEmpl_{it}$ represents the log of total full-time employment of i-th firm in all sectors at time t. $lnWage_{it}$ stands for the log of average annual wages and salaries (real) paid by the firms at period t. Unfortunately the BLS database does not include any specific division of skill-unskilled employment. However, the database provides information on employment of each firm categorised according to job types. Based on this information, working proprietors to managerial employees have been used as skilled workers and all other employees have been classified as unskilled. The ratio of the firm specific skilled-unskilled employment for i-th firm at t-th period has been measured by the variable $SkUnsk_{it}$. This skilled-unskilled division of workers has limitations. One problem associated with this classification may be that non-managerial workers who are skilled are being classed as unskilled and this may affect the

[12] The other firms had to be excluded from the sample due to their missing values for any of the required data.

skilled/unskilled employment estimations. But there is no other division available in BLS data that could be used as a better proxy for skilled and unskilled workers than the one used in this study. Also, the ratio of these two types of workers suggests that the classification could be a useful representation of the skill levels. There is no other dataset for Australia that provides detailed plant level breakdown of employment by type and by industry that could be used to compute skilled-unskilled employment ratio to be used in this study. Also, there appears to be no division of wage rates provided in the BLS database that could be used as a proxy for the skilled-unskilled wages.

$lnSale_{it}$ has been measured by taking logarithms of total yearly sales (real) of each firm at period *t*. $R\&DIntens_{it}$ has been calculated as firm specific expenditure (real) on research and development divided by that firm's total sales (real) at each period, which reflects the direct involvement of any firm in R&D activities. $ExpShare_{it}$ has been measured as total real exports divided by total real sales of each firm at each period.[13]

Table 5.1 presents the summary statistics (means and standard deviations) of the variables by sector for the three years (1995-96, 1996-97, and 1997-98). Among all the sectors manufacturing firms appear to be the largest in terms of average number of workers followed by firms in the mining and cultural & recreational services sectors. The statistics on ratio of skilled-unskilled workers show that firms in mining, manufacturing, and wholesale trade sectors are relatively less skill intensive than firms in the other sectors, which are mainly service sector industries.

[13] Table 5.A1 in appendix A5.II lists all the dependent and explanatory variables used in this chapter.

Table 5.1: Summary Table by Sector, 1995-96 to 1997-98
Means (S.D.) of Key Variables

	Mining			Manufacturing			Construction			Wholesale		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Sk.Emp.	2.985	2.542	2.396	2.846	1.689	2.790	1.859	1.874	1.876	2.655	2.818	2.688
(No.)	(2.553)	(2.328)	(2.618)	(3.110)	(1.654)	(2.577)	(1.020)	(1.078)	(1.065)	(2.562)	(2.893)	(2.568)
Unsk.Emp	7.017	6.793	6.325	11.297	11.052	11.575	1.703	1.839	1.883	5.976	5.691	5.526
(No.)	(19.830)	(19.731)	(17.818)	(21.595)	(20.731)	(21.752)	(5.578)	(6.110)	(6.325)	(12.378)	(11.795)	(12.308)
Total Emp	10.002	9.335	8.691	14.143	12.741	14.357	3.562	3.713	3.758	8.631	8.509	8.207
(No.)	(21.062)	(21.309)	(19.576)	(23.634)	(21.534)	(23.513)	(6.154)	(6.722)	(6.904)	(14.114)	(13.652)	(13.999)
Real R&D	38.969	37.946	38.516	13.985	9.434	13.848	0.207	0.203	0.209	1.473	2.411	2.980
('000)	(344.867)	(506.092)	(359.055)	(128.889)	(77.280)	(108.245)	(2.192)	(4.672)	(8.623)	(19.505)	(31.027)	(42.678)
Real Export	2525.702	3465.938	1764.011	244.927	252.205	241.363	6.773	0.094	0.310	465.239	363.475	380.628
('000)	(15433.840)	(31899.810)	(12315.910)	(2492.411)	(2235.143)	(2352.370)	(481.299)	(6.734)	(14.588)	(16665.750)	(10107.70)	(14363.290)
Real Sales	5115.875	4812.221	2936.273	2127.929	2191.788	2271.387	546.029	537.879	591.157	3817.932	3628.535	3619.384
('000)	(26336.510)	(35623.840)	(12663.230)	(6121.988)	(6341.012)	(6393.333)	(1610.823)	(1923.266)	(2280.078)	(21647.35)	(22098.69)	(23559.830)
Real Wages	18.690	24.2649	28.808	20.218	24.775	20.481	12.892	11.131	12.988	20.406	18.408	18.586
('000)	(16.486)	(17.468)	(19.295)	(10.285)	(20.209)	(11.487)	(12.839)	(14.936)	(13.287)	(12.635)	(14.413)	(14.637)
R&DIntens	0.019	0.010	0.019	0.010	0.008	0.009	0.0004	0.001	0.001	0.001	0.002	0.002
	(0.097)	(0.068)	(0.138)	(0.059)	(0.052)	(0.048)	(.003)	(0.004)	(0.010)	(0.014)	(0.014)	(0.014)
ExpShare	0.183	0.222	0.179	0.078	0.084	0.074	0.005	0.003	0.001	0.057	0.054	0.054
	(0.384)	(0.424)	(0.418)	(0.195)	(0.211)	(0.186)	(.071)	(0.044)	(0.009)	(0.211)	(0.197)	(0.206)
Skilled-	0.495	0.560	0.532	0.423	0.228	0.366	0.862	0.820	0.860	0.584	0.581	0.575
Unsk. Empl.	(0.617)	(0.952)	(1.393)	(0.717)	(0.448)	(0.469)	(1.007)	(0.921)	(0.990)	(1.365)	(0.868)	(0.966)

Note: Weighted means have been reported. Values are in real terms (1989-90=100) in Australian dollar

Table 5.1: Summary Table by Sector, 1995-'96 to 1997-'98 (Continued)
Means (S.D.) of Key Variables

	Retail Trade			Accommodation, Cafes & Restaurants			Transport & Storage			Finance & Insurance		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Sk.Emp.	2.120	2.163	2.227	2.093	2.258	2.106	2.138	2.146	1.894	1.846	1.804	1.819
(No.)	(1.565)	(1.447)	(1.728)	(1.604)	(1.658)	(1.547)	(1.805)	(1.884)	(1.963)	(3.576)	(2.313)	(2.918)
Unsk.Emp	3.492	3.609	3.475	5.554	5.944	5.621	3.492	4.138	4.150	1.991	1.786	1.970
(No.)	(7.510)	(7.331)	(7.379)	(8.208)	(9.126)	(8.670)	(9.803)	(11.639)	(11.461)	(7.568)	(7.073)	(7.395)
Total Emp	5.612	5.772	5.697	7.647	8.203	7.707	5.630	6.284	6.036	3.837	3.591	3.787
(No.)	(8.443)	(8.277)	(8.412)	(8.749)	(9.774)	(9.279)	(10.919)	(12.793)	(12.512)	(9.831)	(8.697)	(9.589)
Real R&D	0.146	0.215	0.230	0.365	1.009	0.464	0.078	0.038	0.139	1.252	0.791	0.315
('000)	(5.927)	(6.586)	(9.550)	(4.697)	(12.975)	(6.465)	(1.544)	(0.902)	(2.755)	(29.777)	(21.694)	(13.361)
Real Export	2.210	1.677	0.483	2.341	0.967	0.202	31.818	28.574	26.646	3.308	2.550	3.273
('000)	(167.954)	(134.817)	(29.951)	(29.482)	(10.841)	(4.969)	(546.906)	(343.969)	(319.834)	(44.655)	(17.594)	(135.109)
Real Sales	1021.389	973.659	956.389	568.594	534.426	492.538	737.736	832.344	710.228	421.246	472.678	393.388
('000)	(3870.196)	(3997.002)	(4165.637)	(893.956)	(863.231)	(899.796)	(3058.277)	(3429.543)	(3480.975)	(2908.414)	(3139.624)	(2724.530)
Real Wages	12.780	11.531	11.817	13.098	10.802	11.393	16.096	16.410	15.309	18.781	14.524	15.857
('000)	(8.784)	(8.243)	(9.432)	(8.818)	(8.160)	(13.012)	(13.381)	(13.287)	(12.529)	(68.461)	(16.884)	(18.860)
R&DIntens	0.0002	0.0006	0.004	0.0005	0.002	0.005	0.0002	0.00005	0.0001	0.002	0.005	0.003
	(0.003)	(0.007)	(0.045)	(0.005)	(0.015)	(0.052)	(0.002)	(0.0005)	(.0009)	(.0.020)	(0.055)	(.030)
ExpShare	0.005	0.005	0.0003	0.005	0.002	0.001	0.033	0.035	0.031	0.006	0.005	0.097
	(0.062)	(0.068)	(0.005)	(0.044)	(0.018)	(0.015)	(0.175)	(0.174)	(.159)	(0.043)	(0.047)	(1.259)
Skilled-	0.682	0.635	0.639	0.686	0.558	0.560	0.556	0.667	0.601	0.936	0.848	0.758
Unsk Empl.	(1.146)	(0.837)	(0.900)	(0.807)	(0.710)	(0.682)	(0.699)	(1.270)	(.845)	(1.047)	(0.835)	(.797)

Note: Weighted means have been reported. Values are in real terms (1989-90=100) in Australian dollar

Table 5.1: Summary Table by Sector, 1995-'96 to 1997-'98 (Continued)
Means (S.D.) of Key Variables

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sectors		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Sk.Emp. (No.)	1.883 (1.996)	2.004 (1.897)	1.978 (1.992)	1.924 (2.288)	1.760 (2.308)	1.682 (1.583)	1.605 (0.965)	1.538 (1.073)	1.489 (1.040)	1.800 (1.894)	1.922 (1.873)	1.952 (1.922)
Unsk.Empl. (No.)	2.777 (8.551)	2.788 (8.858)	2.983 (9.430)	7.382 (11.889)	8.121 (13.264)	8.154 (15.335)	2.014 (3.126)	2.147 (3.690)	2.366 (4.237)	3.253 (9.223)	3.388 (9.389)	3.609 (9.937)
Total Emp (No.)	4.660 (9.825)	4.792 (10.080)	4.959 (10.628)	9.307 (13.244)	9.881 (14.543)	9.836 (16.465)	3.619 (3.599)	3.684 (4.230)	3.854 (4.757)	5.053 (10.399)	5.310 (10.552)	5.556 (11.075)
Real R&D ('000)	4.489 (69.903)	6.886 (157.659)	8.471 (188.901)	0.068 (3.183)	1.357 (18.015)	0.988 (12.186)	0.0 (0.0)	0.013 (0.374)	0.015 (1.168)	1.858 (46.313)	2.570 (81.737)	3.208 (103.011)
Real Export ('000)	9.082 (283.008)	8.828 (238.872)	6.035 (147.604)	4.541 (78.649)	5.054 (77.087)	4.266 (64.024)	0.449 (7.396)	0.627 (11.684)	1.116 (156.948)	53.491 (4216.887)	54.661 (3217.928)	52.432 (3946.801)
Real Sales ('000)	371.419 (1489.153)	358.441 (1552.562)	375.962 (1866.871)	933.747 (2966.978)	864.269 (2991.402)	724.452 (3077.482)	176.753 (362.244)	172.412 (331.358)	176.039 (528.126)	824.061 (7002.358)	831.636 (7275.631)	859.070 (7012.399)
Real Wages ('000)	15.973 (13.697)	14.502 (16.010)	15.857 (17.181)	17.024 (62.713)	12.209 (19.529)	11.182 (14.465)	11.078 (9.311)	8.606 (8.487)	8.725 (8.905)	14.289 (19.775)	13.088 (13.756)	14.275 (14.217)
R&DIntens	0.010 (0.065)	0.013 (0.113)	0.020 (.209)	0.0002 (0.001)	0.002 (0.012)	0.006 (.0547)	0.0 (0.0)	0.0001 (0.0007)	0.0001 (.001)	0.005 (0.042)	0.008 (0.194)	0.007 (0.089)
ExpShare	0.029 (0.140)	0.027 (0.137)	0.022 (.121)	0.017 (0.116)	0.013 (0.104)	0.019 (.140)	0.002 (0.017)	0.002 (0.025)	.006 (.050)	0.043 (0.167)	0.050 (0.261)	0.047 (0.347)
Skilled-Unsk. Empl	0.820 (1.334)	0.656 (0.942)	0.587 (.863)	0.406 (0.812)	0.366 (0.552)	0.634 (.634)	0.736 (0.763)	0.557 (0.474)	.694 (1.258)	0.620 (1.041)		0.555 (0.834)

Note: Weighted means have been reported. Values are in real terms (1989-90=100) in Australian dollar

Mining is one of the unskilled intensive industries that record the highest average volume of firm specific exports and exports as a ratio of total sales (ExpShare). Similarly, firms in the other two unskilled intensive sectors mentioned above, viz., manufacturing, and wholesale trade, possess the second and third largest volume of exports, respectively. Firms in other industries export a very small or negligible proportion of their total sales (Table 5.1).

Table 5.1 also shows the firm specific average spending on R&D in each sector. The highest amount of average R&D expenditure and R&D as a ratio of total sales are found to be the highest for mining firms. It can be seen from the table that manufacturing and wholesale trade firms also spend significant proportion of their sales on R&D, whereas, firms in the rest of the sectors spend very small amount on R&D both in volume and as a share to their total sales.

$Union_{it}$ is the categorical variable that measures the percentages of employees who are members of any labour institution in period t. Another categorical variable, Age_{it} captures the age of the firms in different periods. Tables 5.2A and 5.2B present the percentages of firms in each sector by different categorical variables that have been used in the analysis over the three year period. Percentages of the firms having different proportions of union members employed (shown by the variable $Union_{it}$) have been presented in Table 5.2A. The percentages of firms falling in different age groups (Age_{it}) have been also reported in Table 5.2A. The table shows that in manufacturing firms, the highest percentages of employees are members of trade unions compared to all other sectors for all the three years. Around 40 percent of the manufacturing firms have some proportion of employees who are members of trade unions in 1995-96 and the ratio declined to 35 percent by 1997-98. However, percentages of firms having unionised employees declined over time in all the sectors. For example, in 1995-96, both construction and transport & storage sectors had about 35 percent of firms having employees who were union members, and the proportion of such firms declined to about 22 percent and 24 percent, respectively, by 1997-98. Mining industry also had high percentage of firms having unionised employees (though dropped from 30 percent to 22 percent) over these years. One clear trend of unionisation is that, the percentages of firms having unionised workers have been falling over the years in every sector. Another important fact to notice in Table 5.1, 5.2A and 5.2B is that, manufacturing sector, which has been facing increased competition from overseas with trade liberalisation, possesses the highest percentage of firms that have unionised workers. Note that, despite the fact that percentage of firms having unionised workers declined over years, manufacturing sector still continued to have the highest proportion of firms having their workers unionised. The high unionisation could be resulting from the protection this sector had been enjoying and the declining rate of firms with unionised employees could be a consequence of reduced protection. As the firms lose protection, they are expected to be competitive and efficient; and in the long run the strength of unions would fade away.

Table 5.2A also presents the percentages of firms in different age groups by sectors. It is revealed from Table 5.2A that around 40 to 50 percent of the firms belong to the top two age groups, (between the age of 10 to 20 years and 20 years or more) for most of the sectors in all years. Among these, in manufacturing industry 70 percent of the firms have been found to be older than 9 years in 1997-98 (Table 5.2A). Similarly, 61 percent of wholesale trade firms are in the age group of 10 years or above in 1997-98.

To capture the effects of technological change on labour market, few dummy variables have been used in this chapter. Among the dummy variables, *R&D* represents firms that spent or paid some one else to perform research and development or the firms that had not done so. *AcctSoft* represents the firms that had any major increase in the use of accounting softwares or the firms that had not. *AdmComp* indicates whether the firms had any major increase in the use of administrative computer system or whether the firms had not. *ProdTech* represents the firms that had any major increase in production technology or the firms that had not. Another dummy variable, *NewInv*, gives the information on the firms' introduction of any new product or service in the previous year. The dummy variable, *Intgood*, captures the possibility that the firm would introduce any new product or services in next three years.

Table 5.2A: Summary Tables - Percentages of Categorical Variables by Sector

	Mining			Manufacturing			Construction			Wholesale		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Union Member (% of Firms)												
None	70.00	76.00	77.97	61.87	62.89	65.87	64.81	67.70	78.15	78.16	80.97	82.7
Up to 10%	5.00	...	8.47	11.83	11.57	10.30	7.04	6.53	8.62	11.59	9.44	9.96
11% to 25%	2.50	2.00	...	6.21	5.79	6.55	1.48	3.44	1.85	4.90	4.44	3.80
26% to 50%	2.50	4.00	5.08	7.40	7.74	8.17	4.81	4.12	5.54	2.38	1.81	1.70
51% to 75%	10.00	8.00	8.47	7.40	7.32	9.11	7.41	5.50	5.85	1.49	1.81	1.83
76% to 100%	10.00	10.00	...	5.28	4.68	...	14.44	12.71	...	1.49	1.53	...
Age of firms (% of Firm)												
less than 2 yrs.	12.50	14.00	25.42	1.79	0.51	...	8.52	8.59	15.69	7.28	6.11	7.47
2 to less than5 yrs	17.50	20.00	20.34	12.60	8.60	5.11	18.52	16.15	12.92	11.74	12.64	13.24
5 to less than 10 yrs	22.50	12.00	8.47	27.06	26.55	24.6	25.93	25.09	24.62	21.84	20.14	17.96
10 to less than 20)yrs	30.00	34.00	27.12	29.79	31.57	36.34	30.00	28.18	26.77	28.97	28.61	29.36
20 yrs or more	17.50	20.00	18.64	28.77	32.77	33.96	17.04	21.99	20.00	30.16	32.50	31.98

Table 5.2A: Summary Tables -Percentages of Categorical Variables (Continued)

	Retail Trade			Accommodation, Cafes & Restaurants			Transport & Storage			Finance & Insurance		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Union Member (% of Firms)												
None	89.57	90.45	90.96	86.52	81.58	83.09	64.00	64.89	75.38	87.73	86.39	84.13
Up to 10%	7.39	6.04	7.23	3.93	7.89	8.21	10.86	7.45	7.54	5.52	6.51	5.29
11% to 25%	1.09	1.95	0.90	3.93	3.68	4.83	5.14	4.79	4.02	0.61	3.55	5.29
26% to 50%	1.09	1.17	0.54	1.12	1.58	2.90	6.29	8.51	7.04	4.29	1.78	4.23
51% to 75%	0.43	0.19	0.36	0.56	2.63	0.97	5.14	5.32	6.03	0.61	1.18	1.06
76% to 100%	0.43	0.19	...	3.93	2.63	...	8.57	9.04	...	1.23	0.59	...
Age of firms (% of Firms)												
less than 2 yrs.	10.43	10.92	11.75	11.80	8.95	12.56	10.29	9.57	10.55	7.98	5.33	14.29
2 to less than5 yrs	17.83	17.54	17.00	19.66	22.11	21.26	18.86	15.96	13.57	17.18	15.38	15.34
5 to less than 10 yrs	30.43	28.27	26.04	28.09	26.84	25.12	22.29	22.87	23.12	29.45	27.81	21.16
10 to less than 20)yrs	24.35	26.12	28.21	19.10	18.42	19.32	26.29	26.60	28.14	26.99	31.95	32.8
20 yrs or more	16.96	17.15	17.00	21.35	23.68	21.74	22.29	25.00	24.62	18.40	19.53	16.4

Table 5.2A: Summary Tables - Percentages of Categorical Variables (Continued)

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sectors		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
Union Member (% of Firms)												
None	88.69	89.45	90.98	75.00	74.07	79.83	88.00	90.18	94.21	76.09	76.98	80.15
Up to 10%	4.94	5.20	4.85	11.11	12.96	10.92	7.00	4.46	2.48	8.63	8.25	7.95
11% to 25%	2.71	2.08	1.53	5.56	2.78	5.04		0.89	0.83	3.73	3.67	3.77
26% to 50%	1.27	1.49	2.36	3.70	4.63	1.68	1.00	0.89	0.83	4.07	4.13	4.30
51% to 75%	0.80	0.45	0.28	2.78	1.85	2.52	1.00	1.79	1.65	3.61	3.43	3.83
76% to 100%	1.59	1.34	...	1.85	3.70		3.00	1.79		3.87	3.53	
Age of firm (% of Firms)												
less than 2 yrs.	8.76	10.10	10.26	15.74	11.11	13.45	13.00	10.71	12.4	13.14	8.83	10.02
2 to less than5 yrs	19.11	16.34	15.26	20.37	16.67	15.97	22.00	17.86	16.53	15.70	14.92	23.60
5 to less than 10 yrs	32.32	27.49	26.49	22.22	25.00	27.73	28.00	29.46	25.62	25.58	25.02	46.81
10 to less than 20)yrs	28.03	31.35	32.87	25.00	28.70	24.37	22.00	25.00	28.93	25.58	27.76	76.66
20 yrs or more	11.78	14.71	15.12	16.67	18.52	18.49	15.00	16.96	16.53	20.00	23.39	100

Table 5.2B: Summary Tables - Percentages of Categorical Variables (Continued)

	Mining			Manufacturing			Construction			Wholesale		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
If the Firms Performed or Paid Others to Perform R&D (R&D) (% of Firms)												
Yes	22.5	14.00	18.64	21.11	17.96	19.15	2.59	3.44	2.46	5.94	7.50	8.39
Major Increase in the use of Accounting Soft Ware (% of Firms)												
AcctSoft	15.00	16.00	18.64	23.74	18.98	20.77	14.44	16.15	16.62	25.41	18.89	20.71
Major Increase in Other Administrative Computer Systems (% of Firms)												
AdmComp	25.00	24.00	18.64	30.89	23.66	25.36	17.78	14.78	17.23	32.39	25.56	24.64
Major Increase in Production Technology												
ProdTech	15.00	10.00	11.86	30.72	24.51	24.17	9.26	5.84	8.31	18.28	9.31	12.19
If the Firms Introduced New Products or Services (NewInv) (% of firms)												
Yes	7.50	4.00	3.39	32.51	22.38	22.3	11.11	7.90	4.92	17.98	12.64	12.06
If the Firms Expect to Introduce any New Product in three years (Intgood) (% of firms)												
Yes	5.00	14.00	13.56	41.87	37.62	34.21	18.15	12.03	9.54	47.25	42.08	38.93

Table 5.2B: Summary Tables-Percentages of Categorical Variables (Continued)

	Retail Trade			Accommodation, Cafes & Restaurants			Transport & Storage			Finance & Insurance		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
If the Firms Performed or Paid Others to Perform R&D (R & D) (% of firms)												
Yes	1.52	3.70	2.35	1.69	2.11	2.42	3.43	2.66	3.52	3.68	4.14	4.23
Major Increase in the use of Accounting Software												
AcctSoft	19.78	14.81	15.73	17.98	8.95	15.46	23.43	15.43	17.59	22.70	15.38	19.05
Major Increase in Other Administrative Computer Systems (% of Firms)												
AdmComp	23.70	15.20	18.44	21.35	14.21	16.91	25.71	18.62	21.61	39.26	26.04	23.28
Major Increase in Production Technology												
ProdTech	16.09	5.07	13.56	6.74	1.05	7.73	9.71	4.79	14.57	25.77	6.51	17.99
If the Firms Introduced New Products or Services (NewInv) (% of Firms)												
Yes	18.26	7.80	7.23	16.29	5.26	6.76	16.57	9.57	12.06	16.56	10.65	10.58
If the Firms Expect to Introduce any New Product in three years (Intgood) (% of Firms)												
Yes	25.87	24.37	22.24	17.98	11.58	17.39	18.29	14.36	14.07	19.63	22.49	21.16

Table 5.2B: Summary Tables-Percentages of Categorical Variables (Continued)

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sectors		
Variables	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98	1995-96	1996-97	1997-98
If the Firms Performed or Paid Others to Perform R&D (R & D) (% of firms)												
Yes	7.32	6.69	7.91	2.78	5.56	7.56	0	1.79	1.65	9.64	9.11	9.67
Major Increase in the use of Accounting Software												
AcctSoft	21.66	14.56	16.5	12.96	10.19	15.13	12.00	9.82	9.92	20.38	15.79	18.17
Major Increase in Other Administrative Computer Systems (% of Firms)												
AdmComp	29.94	23.03	21.22	24.07	18.52	13.45	19.00	10.71	11.57	26.22	20.32	21.36
Major Increase in Production Technology (% of Firms)												
ProdTech	21.34	9.36	14.29	15.74	10.19	9.24	7.00	6.25	5.79	19.88	12.38	15.74
If the Firms Introduced New Products or Services (NewInv) (% of Firms)												
Yes	18.95	11.00	10.26	21.30	8.33	10.08	16.00	7.14	4.96	21.61	13.53	13.07
If the Firms Expect to Introduce any New Product in three years (Intgood) (% of Firms)												
Yes	24.04	21.25	19	19.44	17.59	16.81	24.00	17.86	23.14	30.52	27.52	26.96

In Table 5.2B the percentage of firms that spent or paid some one else to perform R&D (R&D) is given by sector. Coupled with this, the table also presents the percentages of firms that had any type of major increase in the use of accounting software, ($AcctSoft_{it}$), administrative computer system, ($AdmComp_{it}$) and in production technology, ($ProdTech_{it}$), by sector for the three different years. Also, the table includes the percentages of firms that introduced any new product or services, ($NewInv_{it}$), for all the sectors. As expected, the sectors that spent the most on R&D (apparent from the mean of the variable R&DIntens) had the higher percentages of firms spending directly or indirectly on research and development. For example, in the year 1997-98, manufacturing sector had 19.15%, mining sector had 18.64%, and wholesale trade sector had 8.37% of firms spending on some kind of R& D activities. In the rest of the sectors, the percentage of firms spending on R&D is very small but the firms in all the sectors show a growing trend of spending on R&D. Table 5.2B shows that in cultural & recreational sector 2.78 percent of the firms spent directly or indirectly on R&D in 1995-96, which grew to 7.56 percent by 1997-98. Personal & other services sector had no firms who were paying on R&D in 1995-96 but had 1.56 percent firms spending on R&D by 1997-98. Similar results have been found for other technological change variables, e.g., *AcctSoft*, *AdmComp*, and *ProdTech*. Manufacturing sector is the leading sector for all these advancement in technological change indicators, mainly followed by mining and wholesale trade sectors. Increased competition from overseas and the need to gain operative efficiency in a more liberalised regime seem to have hastened technological change in the export-oriented sectors, such as manufacturing, mining, and wholesale trade.

The computer usage variables are available from the BLS database for the year 1996-97 only. $ComBus_i$ is one of the dummy variables on computer usage of the firms that shows whether the firm uses computer in their business or not. $NetAcc_i$, another dummy variable, gives the information if the firm has access to Internet or not. $ComLong_i$ is a categorical variable that presents the number of years of computer use by each firm in *i*-th sector. $CompR_i$ measures the proportion of employees in each firm who use computers relative to the total number of employees in that firm. Another variable on computer usage, $EmpCom_i$, is measured as the number of employees who use computer at least once a week in each firm divided by total employment of the firm.

Table 5.3 presents the summary of these computer usage variables. The table reveals that the share of employees who are using computers relative to total employment in a firm, (CompR), is the smallest in the accommodation, cafes & restaurants and construction sectors. The manufacturing and mining firms also have smaller proportion of employees who use computers relative to the total employment (0.39 each). However, the ratio is as high as 0.59 in the wholesale trade industry. Note that the mean values of *CompR* in some other services sectors firms (e.g., transport & storage, personal & other services) are similar to manufacturing and mining. On the other hand, firms in the skill-intensive services sectors (e.g., finance & insurance, property & business) have higher average *CompR* (0.81 and 0.66, respectively).

Even though the average of *CompR* in the manufacturing firms is smaller than those in firms in other industries, 90 percent of the firms use computers (ComBus) in this sector. In fact, manufacturing firms has the highest percentage of average computer usage among firms in all sectors, followed by 81, 79, and 76 percent in firms in the property & business services, cultural & recreational services, and finance & insurance services sectors, respectively. The variable *ComLong* represents how long the firms had been using computers. With regard to *ComLong*, it is found that in the manufacturing sector 58 percent of the firms have been using computers for more than 5 years (Table 5.3). This is followed by the property & business services and finance & insurance services sector firms, each of which has 44 percent of the firms that use computers for more than 5 years. The statistics on firms' Internet access record, (NetAcc), show that the property & business sector leads with 50 percent firms accessing internet followed by the mining, wholesale trade and finance & insurance sectors. Also, a moderate proportion of around 39 percent of manufacturing firms has access to internet.

Table 5.3: Summary Tables - Computer Use Variables, 1996-97

Variables	Mining	Manufacturing	Construction	Wholesale	Retail Trade	Accommodation, Cafes & Restaurants	Transport & Storage	Finance & Insurance	Property & Business	Cultural & Recreational Services	Personal & Other Services	Combined Sectors
Average No. of Employees use Computers	3.276 (13.122)	4.232 (10.756)	0.816 (2.410)	4.866 (11.934)	1.988 (5.564)	1.458 (3.267)	2.095 (7.240)	2.741 (8.285)	2.907 (7.205)	3.244 (6.200)	0.956 (2.488)	2.058 (6.331)
Average CompR	0.389 (0.394)	0.392 (0.552)	0.281 (0.470)	0.590 (0.430)	0.401 (0.451)	0.190 (0.310)	0.344 (0.450)	0.814 (0.798)	0.655 (0.529)	0.507 (0.455)	0.379 (0.727)	0.453 (1.045)
How long the firms have been using computers (ComLong) (% of Firms)												
0	31.88	10.20	38.53	44.36	30.00	44.29	27.88	24.26	18.57	21.32	42.19	53.37
1	18.84	12.76	18.53	17.56	20.17	21.00	21.63	15.32	16.75	28.68	21.09	12.80
2	11.59	18.88	19.12	15.00	17.41	16.89	19.23	16.17	20.26	20.59	16.41	10.20
3	37.68	58.16	23.82	23.08	32.41	17.81	31.25	44.26	44.42	29.41	20.31	23.62
NetAcc (% of Firms)												
	49.28	38.95	17.06	44.62	21.38	15.98	22.60	43.40	50.00	41.18	16.41	20.21

It is apparent from Table 5.3 that the services sector firms are more computer-intensive (in terms of proportion of employees using computers) regardless of their relative sizes. Wholesale trade sector firms also have significant computer use activities though only a small proportion of businesses (23 percent) in this sector are using computer for over 5 years. Table 5.3 further shows that firms in manufacturing and mining industries that spend more on R&D and are more export-oriented, have moderate use of computers in terms of *CompR* and *NetAcc*. However, due to data constraint, changes in computer usages by firms in different sectors over time could not be identified.

5.4 Results

Within/Between Industry Decompositions

Within and *between* industry components of shifts in skill demand have been calculated based on equation (5.7) and using a sample of 1126 manufacturing firms of Australia contained in the BLS database. The results have been aggregated at the two-digit levels of manufacturing industries based on ANZSIC scheme and presented in Table 5.4. The table shows the decomposition of percent annual changes in employment share of skilled workers over the period 1995-1998. These decompositions of the changes in employment reveal nature of the shifts in skilled demand in Australia due to changes in technology and other factors.

As Table 5.4 indicates, between 1995 and 1998, share of skilled employment in total manufacturing employment of Australia has increased by 5.111 percent. This total increase in relative share of skilled workers has been due to *within* industry changes (4.049 percent) and b*etween* industry changes (1.062 percent), as revealed by the relevant columns of Table 5.4.

Table 5.4 *Within* and *Between* Industry Decomposition of the Changes in the Employment of Manufacturing Skilled Workers in Australia: 1995-96 to 1997-98.
(Annual Percent Change)

ANZSIC Industry & Code	Within Industry	Between Industry	Total	Number of Observations
21 Food, Beverage and Tobacco	-0.007	0.647	0.640	130
22 Textile, Clothing, Footwear & Leather	0.276	-1.286	-1.01	96
23 Wood and Paper Product	0.713	0.102	0.815	57
24 Printing, Publishing & Recorded Media	0.529	2.552	3.080	72
25 Petroleum, Coal, Chemical & Associated Product	0.126	-0.579	-0.452	146
26 Non-Metallic Mineral Product	0.102	0.482	0.583	48
27 Metal Product Manufacturing	0.904	0.269	1.173	168
28 Machinery & Equipment	0.996	-0.415	0.581	297
29 Other Manufacturing	0.410	-0.709	-0.299	110
Total	4.049	1.062	5.111	1126

Source: Author's calculations using BLS data set, 1995-1998. The plant level data have been used for 1126 manufacturing plants in different industries. Results have been aggregated in two-digit industry level. The variables have been weighted using weights for point in time variables provided in BLS Spreadsheet.

In other words, while 79.22 percent of total change has been due to *within* industry skill upgrading, the rest 20.78 percent could be attributed to other factors such as international trade. Employment change patterns of the various sub divisions of manufacturing industry reveal that most of the industries experienced an increase in the skill composition *within* the industry (Table 5.4). The only industry that saw a small reduction in the skill composition is Food, Beverages and Tobacco industry. Non-Metallic Mineral Product and Printing, Publishing & Recorded Media industries experienced higher *between* industry effects. These higher b*etween* industry effects imply that in these two industries, increase in international trade has primarily caused shift in labour demand from unskilled intensive firms to skill-intensive firms. On the contrary, higher *within* industry effects recorded by all other industries indicate that in these industries, skill-biased technological change shifted the skill composition of labour demand.

The above results also confirm the findings of some earlier studies conducted in Australia. Borland and Foo (1996) reported that the predominant changes in the share of production (unskilled) employment in Australian manufacturing have been the changes *within* over three different periods, viz., 1952-1968, 1969-1977, and 1978-1987. They found that in each of these three periods, the share of production workers in total employment declined. They also showed that over the period 1978-1989, 87 per cent of the changes were *within* industries. In a separate study, Berman, Bound, and Machin (1998) found that over the periods of 1970-1980 and 1980-1990, bulk of skill upgrading in Australia occurred *within* rather than *between* industries. They estimated that on average, 52 percent and 92 percent skill upgrading occurred *within* industries each year over the period 1970-1980 and 1980-1990, respectively.

Technological Change and Australian Labour Market

Employment equations (5.8'), wage equations (5.9'), and skilled-unskilled employment ratio equations (5.10') have been estimated as random effect panel regression models. The estimated results, reported in Table 5.5, reveal the effects of various technological and controlled variables on employment, average real wages, and skilled-unskilled employment ratio of firms in various sectors over the period 1995-96 to 1997-98. Note that the same set of independent variables has been used in each regression and that the estimated coefficients have been reported in three columns under each industry category with names of the corresponding dependent variables as the column titles. The standard errors have been reported in parentheses. Each equation also includes the time dummies for the years 1997 and 1998. To determine the robustness of the random effect panel regression estimates compared to fixed effect models, Hausman specification test[14] and Breusch-Pagan Lagrange multiplier tests have been conducted. The relevant χ^2 statistics have been reported for each separate equation in the second and third last rows of Table 5.5.

The results indicate that the share of R&D spending in total sales (R&DIntens) has positive effects on wages paid by firms in most of the sectors. In other words, technological change through increased spending on research and development activities raises the average wages paid by the firms. There appears to be one exception to this phenomenon, for firms

[14] Hausman specification test statistics for most of the estimated equations have been significant. This shows that RE estimates may not be suitable for the model estimation. Hence, the Fixed Effects regressions have been run for all the results. The results from FE are not substantially different from the results from RE most of the time.

in the finance & insurance industry. Higher R & D intensity seems to lower average wages in these firms (as indicated by the negative and significant estimated coefficient). Table 5.5 also indicates that although firm specific employment seems to increase with higher R & D intensity, such effects are not significant in many of the sectors. Note that the share of R & D in sales does not have significant effect on employment in industries with higher spending on R&D such as mining, manufacturing, and wholesale trade. As opposed to this, *R&DIntens* exerts strong positive effect on wages and employment in industries that spend relatively less on their R & D activities (such as accommodation, cafes & restaurants, property & business, cultural & recreational services sectors) (Table 5.5).

However, combining all the sectors yields slightly different results as indicated in the last three columns of Table 5.5. The relevant coefficient estimates suggest that R&D intensity in Australian firms in general, tend to have significant positive effect on their employment but not on the firm specific average wages.

Estimated coefficients of the skilled-unskilled employment ratio equation show that the R&D intensity fails to provide any significant explanation of the changes in skill mix of employment in firms in almost all the industries. Note that these coefficients are negative for most of the industries. In a recent study, De Laine, et al., (2000) found that R&D intensity has significant and positive effects on skilled-unskilled wage differentials in various industries in Australia. They showed that there has been substantial variation of the effects of R&D on skilled-unskilled employment ratio across industries, with much stronger effects observed in some industries. Allen (2001) identified a series of shifts in labour demand toward educated workers due to change in R&D intensity in the U.S. economy. In his work, Allen (2001) did not find any relationship between the growth of R&D intensity and growth of wages.

One important observation from results presented in Table (5.5) is that in export intensive sectors that are also the unskilled intensive sectors (such as mining and manufacturing), the variable *ExpShare* renders negative impact on average wages paid by the firms. The effect of *ExpShare* on firm specific employment appears to be negative as well (though significant only for manufacturing firms). In the skill-intensive services sectors such as property & businesses or cultural & recreational industries, firms with higher export intensity are likely to see significant rise in their employment (Table 5.5). Export intensity also has negative but insignificant effect on the wages paid by these service sector firms. Based on the estimated equations for the combined sector, the overall evidence suggests that export intensity has significantly positive effect on employment but insignificant effect on firm specific wages. Table 5.5 also shows that export intensity variable has weak but positive effect on skilled-unskilled employment ratio in firms in all the sectors except two sectors. Thus, increased exports have weak but negative effects on unskilled employment of all the sectors. In the wholesale trade industry the effect of export intensity on skilled-unskilled employment ratio is significant and positive. Hence, it is evident that with increased openness, firms in this industry tend to raise their relative skilled employment either by leaving their number of unskilled workers unchanged or by causing the numbers of such workers to decline. Combining this result with the negative but statistically insignificant coefficient of export intensity in the employment equation reveals that higher export intensity would possibly reduce unskilled employment relative to skilled employment in the wholesale trade firms.

As Table 5.5 shows, union density fails to exert any adverse effect on wages in few sectors. In the manufacturing firms, which record the highest union density, higher unionisation seems to fail to show any significant effect on average wages. Union density has positive impact on wages for firms in wholesale trade, accommodation, cafés, & restaurants and in the combined sector. In the employment equations, the estimated coefficients of union density are positive and significant for firms in manufacturing, construction, wholesale trade, finance & insurance, property & business, cultural & recreational sector as well as in the combined sector. Union density has negative and significant effect on skill mix of firms in mining, construction, finance & insurance, property & business and in the combined sector. However, for manufacturing firms, union density and skill mix are significantly and positively related. In an open economy in the long run, increased international competition is likely to cause technological advancement and introduction of new work practices in the businesses. As a result, bargaining power of the workers would fade away and that would put a downward pressure on the employment of especially the low-skilled workers. Haskel and Slaughter (2001) also found negative relationship between union power and technological change (measured by TFPG) in U.K. for the period 1963 to 1986.

Estimated regression coefficients for age of businesses show that older firms pay higher wages in all sectors (as revealed by estimated coefficient of the combined sector). In particular, wages tend to be significantly higher in older firms in mining, manufacturing, wholesale trade, , transport & storage, properties & business, personal & other services industries. In retail trade and personal & other services industries, while wages paid by the older firms tend to rise insignificantly, employment declines significantly. The evidence of age effect on employment has been mixed. The effect is significant and positive for manufacturing and wholesale trade firms. On the contrary, in most of the other sectors the effect is negative but insignificant.

Results presented in Table 5.5 also indicate that in manufacturing and accommodation, cafés, & restaurant industries, the newer firms employ higher relative skilled workers and vice versa. In personal & other services sector older firms employ higher relative skilled workers. Many other studies (e.g., Evans, 1987; Doms et al., 1995, Gretton et al., 2002) also found similar effect of firms' age on their wages and employment. All these studies show that performance of the firms and ages of the firms have been strongly related in most cases.

The other technology indicators used as explanatory (dummy) variables include *R&D*, introduction of new services or products (NewInv), expectation of the introduction of new good within next three years (Intgood), any major increase in the use of accounting softwares, (AcctSoft), other administrative computer system (AdmComp), or in the production technology (ProdTech). These variables do not show any systematic explanatory power in the real wages and employment equations for most of the sectors (Table 5.5). *R&D* dummy has significant (at 5 percent level) positive impact on employment in the wholesale trade firms as well as the in firms in all sectors (at 1 percent level). Estimated coefficients of *R&D* in the skilled-unskilled employment ratio equation show that firms in seven out of eleven sectors have positive, but mostly insignificant, effects. This provides weak evidence of extensive skill-biased technological change in these sectors. For example, in the finance & insurance industry, *R&D* has an insignificant negative effect on wages, insignificant negative effect on employment, and a significant positive effect on skilled-unskilled employment ratio. Altogether the results provide strong evidence of extensive skill-biased technological change via *R&D* in finance & insurance industry. On the other hand, *R&D* has significant negative effect on wages, insignificant negative impact on employment and significant negative effect on skilled-unskilled employment ratio. Hence, the results suggest strong evidence of intensive skill-biased technological change via *R&D* in personal & other services industry.

The technological change indicator *NewInv* has positive effect on employment, wages, and skilled-unskilled employment ratio in wholesale trade firms. However, the variable has significant effect only in employment equation. This provides a weak evidence of the existence of extensive skill-biased technological change in the wholesale trade sector via the variable *NewInv*. In retail trade firms, *NewInv* exerts significant positive effect on wages, insignificant negative effect on employment, and positive effect on skilled-unskilled employment ratio. These results clearly imply that in retail trade firms of Australia, labour demand shifted towards skilled workers, which is also an evidence of extensive skill-biased technological change effects. In cultural & recreational industry as well as in all sectors combined, the evidence shows that *NewInv* significantly and positively affects the skilled-unskilled ratio of workers in various firms, or in other words, *NewInv* significantly causes loss of unskilled jobs in these firms (Table 5.5).

Table 5.5: Estimated Effects of Technological Change on Employment, Wages and Skilled-Unskilled Employment Ratio Panel Regression (Random Effects) Estimates, 1996-97 to 1997-98

	Mining			Manufacturing			Construction			Wholesale Trade		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	InEmpl	InWage	SkUnskEmp	InEmpl	InWage	SkUnskEmp	InEmpl	InWage	SkUnskEmp	InEmpl	InWage	SkUnskEmp
lnSale	0. .313*** (0.039)	0. 344*** (0.053)	-0. 162*** (0.063)	0.640*** (0.009)	0.512*** (0.013)	-0.183*** (0.010)	0.474*** (0.020)	0.496*** (0.034)	-0.244*** (0.031)	0.420*** (0.010)	0.400*** (0.015)	-0.216*** (0.018)
R&DIntens	0. 153 (0. 683)	2.770*** (0. 809)	-0.854 (1.067)	0.222 (0.152)	0.631*** (0.157)	-0.097 (0.184)	-0.773 (2.537)	-1.059 (3.402)	2.988 (3.879)	0.197 (0.856)	0.386 (0.916)	-0.786 (2.023)
ExpShare	-0. 117 (0. 183)	-0. 103(0. 200)	0. 171 (0.291)	-0.201*** (0.052)	-0.083* (0.049)	0.056 (0.057)	0.176 (0.292)	0.021 (0.392)	0.048 (0.527)	-0.015 (0.067)	0.084 (0.067)	0.303** (0.143)
Union	0. 042 (0. 036)	0. 074* (0.041)	-0.107* (0.065)	0.054*** (0.007)	0.008 (0.006)	0.023*** (0.007)	0.048*** (0.012)	0.039*** (0.015)	-0.035* (0.019)	0.054*** (0.011)	0.008 (0.013)	-0.029 (0.029)
R&D	-0. 067 (0.130)	-0.022 (0.154)	0.135 (0.266)	0.018 (0.022)	-0.020 (0.023)	0.001 (0.028)	0.136 (0.125)	0.228 (0.165)	-0.106 (0.197)	0.060** (0.033)	0.066* (0.037)	-0.065 (0.098)
NewInv	0.041 (0.203)	-0.093 (0.243)	-0.270 (0.436)	0.021 (0.018)	-0.002 (0.020)	0.020 (0.024)	0.098* (0.056)	-0.088 (0.078)	0.108 (0.096)	0.034** (0.018)	0.016 (0.021)	0.038 (0.062)
Intgood	0. 208 (0.149)	-0.117 (0.178)	0.790** (0.324)	0.014 (0.015)	-0.005 (0.016)	-0.010 (0.019)	0.027 (0.051)	0.093 (0.070)	-0.079 (0.087)	0.024 (0.015)	-0.011 (0.017)	-0.064 (0.048)
Age	0.005 (0.067)	0.158** (0.066)	0.014 (0.086)	0.036*** (0.011)	0.039*** (0.010)	-0.044*** (0.012)	-0.008 (0.024)	0.025 (0.029)	-0.001 (0.036)	0.037*** (.0136)	0.075*** (0.013)	-0.030 (0.024)
AcctSoft	0.210* (0.118)	-0.259* (0.144)	0.136 (0.086)	0.019 (0.014)	0.009 (0.016)	-0.032* (0.019)	-0.054 (0.036)	0.046 (0.050)	0.019 (0.061)	-0.043*** (0.015)	-0.008 (0.018)	-0.026 (0.052)
AdmComp	-0.000 (0.090)	0.064 (0.110)	0.078 (0.212)	-0.018 (0.012)	0.003 (0.014)	-0.006 (0.016)	0.046 (0.032)	0.016 (0.046)	-0.020 (0.056)	0.041*** (0.013)	-0.000 (0.015)	0.052 (0.045)
ProdTech	-0.012 (0. 084)	0.107 (0.103)	-0.190 (0.189)	0.000 (0.012)	-0.002 (0.013)	0.007 (0.016)	0.002 (0.030)	0.001 (0.042)	0.025 (0.053)	0.006 (0.010)	0.028 (.0125)	-.013 (0.037)
Constant	-0. 287 (0. 372)	1.017*** (0. 381)	1.804*** (0.600)	-2.259*** (0.074)	0.568*** (0.076)	1.957*** (0.078)	-1.387*** (0.136)	0.189 (0.183)	2.577*** (0.225)	-0.931*** (0.094)	0.614 (0.093)	2.598*** (0.173)
R^2	0.633	0.289	0.150	0.818	0.347	0.209	0.692	0.238	0.226	0.709	0.318	0.126
Hausman statistic (χ^2)	111.15***	38.79***	8.70	188.44***	199.38	29.50	160.14***	58.45***	39.96***	465.98***	107.80***	23.75**
Breusch-Pagan statistic (χ^2)	62.97	43.78***	10.36***	1600.59***	569.56	323.59	369.59***	162.64***	112.96***	1282.05***	960.33***	190.38***
No. of Obs.	145	142	127	3525	3483	3380	880	801	654	2146	2090	1982

Note: The standard errors of the estimated coefficients have been given in the parentheses. Equations also include Time Dummy for years 1997 and 1998.
***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 5.5: Estimated Effects of Technological Change on Employment, Wages and Skilled-Unskilled Employment Ratio Panel Regression (Random Effects) Estimates, 1996-97 to 1997-98 (Contd.)

	Retail Trade			**Accommodation, Cafes & Restaurants**			**Transport & Storage**			**Finance & Insurance**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	lnEmpl	lnWage	SkUnskEmp	lnEmpl	lnWage	SkUnsk Emp	lnEmpl	lnWage	SkUnskEmp	lnEmpl	lnWage	SkUnskEmp
lnSale	0.465*** (0.014)	0.517 (0.019)	-0.199*** (0.020)	0.524*** (0.026)	0.730*** (0.035)	0.096** (0.046)	0.535*** (0.026)	0.534*** (0.037)	-0.209*** (0.044)	0.307*** (0.022)	0.266*** (0.030)	-0.109*** (0.028)
R&DIntens	-1.733 (1.912)	2.775 (2.051)	-0.937 (4.646)	2.054*** (0.474)	1.914*** (0.510)	-0.068 (0.628)	-2.214 (19.86)	-22.69 (20.55)	-7.747 (29.81)	0.124 (0.646)	-3.3967** (1.584)	-2.287 (1.8055)
ExpShare	0.297 (0.222)	-0.040 (0.248)	0.005 (0.539)	-1.976*** (0.661)	-0.226 (0.690)	-0.645 (0.916)	0.144 (0.194)	0.071 (0.200)	0.158 (0.296)	0.075 (0.057)	0.096* (0.050)	0.036 (0.050)
Union	-0.007 (0.020)	0.007 (0.021)	-0.045 (0.048)	0.073 (0.022)	0.041* (0.022)	-0.025 (0.028)	0.016 (0.016)	0.030* (0.016)	-0.005 (0.026)	0.143*** (0.038)	0.004 (0.043)	-0.160*** (0.054)
R&D	0.030 (0.061)	0.001 (0.063)	0.073 (0.147)	-0.107 (0.107)	-0.076 (0.113)	-0.021 (0.138)	0.184 (0.142)	-0.029 (0.147)	-0.086 (0.213)	0.182 (0.144)	-0.092 (0.178)	0.387* (0.218)
NewInv	-0.009 (0.028)	0.052* (0.029)	0.062 (0.068)	-0.022 (0.048)	-0.028 (0.051)	0.087 (0.064)	0.007 (0.058)	0.007 (0.061)	0.030 (0.090)	0.059 (0.064)	0.043 (0.080)	0.158 (0.108)
Intgood	0.002 (0.022)	0.007 (0.023)	0.047 (0.053)	-0.003 (0.044)	-0.039 (0.046)	0.122** (0.058)	0.042 (0.060)	-0.052 (0.064)	-0.062 (0.099)	0.093 (.060)	-0.031 (0.073)	-0.163* (0.098)
Age	-0.0476** (0.016)	0.052 (0.016)	-0.000 (0.025)	-0.056 (0.025)	0.052 (0.024)	-0.064* (0.034)	0.014 (0.030)	0.083*** (0.031)	-0.022 (0.048)	-0.047 (0.039)	0.052 (0.039)	0.026 (0.044)
AcctSoft	0.017 (0.020)	0.005 (0.021)	-0.003 (0.050)	0.005 (0.036)	0.024 (0.038)	0.001 (0.048)	0.027 (0.047)	0.004 (0.051)	0.046 (0.076)	0.026 (0.045)	0.018 (0.056)	-0.065 (0.080)
AdmComp	-0.0265 (0.017)	0.023 (0.018)	-0.013 (.043)	0.003 (0.028)	-0.0149 (0.030)	-0.042 (0.037)	0.012 (0.041)	0.006 (0.043)	-0.077 (0.066)	0.013 (0.037)	0.032 (0.046)	0.154** (0.065)
ProdTech	0.017 (0.015)	-0.022 (0.016)	-0.060 (0.038)	0.040 (0.030)	0.023 (0.032)	-0.056 (0.039)	0.014 (0.034)	0.078 (0.036)	-0.030 (0.054)	0.037 (0.034)	0.008 (0.042)	-0.022 (0.060)
Constant	-0.858*** (0.109)	-0.123 (0.104)	2.326 (0.167)	-1.1437 (0.175)	-0.929 (0.163)	0.645 (0.223)	-1.498 (0.202)	0.100 (0.206)	2.2719*** (0.346)	-0.0785 (0.205)	1.720*** (0.212)	1.572*** (0.267)
R^2	0.717	0.347	0.159	0.713	0.596	0.040	0.705	0.376	0.161	0.702	0.248	0.140
Hausman statistic (χ^2)	284.90***	147.27***	33.89***	74.11***	26.94***	19.76*	69.49***	11.23	9.68	760.14** *	31.72***	17.99
Breusch-Pagan statistic (χ^2)	854.27***	601.08***	220.14***	274.17***	183.85***	85.07	242.70** *	180.88** *	32.86***	156.77** *	106.87***	115.73***
No. of Obs.	1519	1482	1398	573	552	530	557	536	486	510	467	367

Note: The standard errors of the estimated coefficients have been given in the parentheses. Equations also include Time Dummy for years 1997 and 1998.
***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 5.5: Estimated Effects of Technological Change on Employment, Wages and Skilled-Unskilled Employment Ratio Panel Regression (Random Effects) Estimates, 1996-97 to 1997-98 (Contd.)

	Property & Business			**Cultural & Recreational**			**Personal & Other Services**			**Combined Sectors**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	lnEmpl	lnWage	SkUnsk	lnEmpl	lnWage	SkUnsk	lnEmpl	lnWage	SkUnsk	lnEmpl	lnWage	SkUnsk
lnSale	0.482*** (0.013)	0.501*** (0.017)	-0.190*** (0.022)	0.426*** (0.029)	0.539*** (0.042)	-0.081 (0.028)	0.544*** (0.033)	0.746*** (0.056)	0.313*** (0.041)	0.466*** (0.004)	0.461*** (0.006)	-0.180*** (0.006)
R&DInten	0.248*** (0.084)	0.321*** (0.085)	-0.136 (0.171)	3.366*** (0.764)	3.077** (1.417)	-0.660 (1.171)	20.419 (33.948)	71.23* (42.702)	54.775 (49.914)	0.091*** (0.023)	0.040 (0.025)	-0.035 (0.111)
ExpShare	0.241* (0.138)	0.022 (0.129)	0.172 (0.233)	1.053*** (0.396)	-0.806 (0.684)	0.455 (0.510)	0.733 (0.760)	-0.581 (0.844)	-0.813 (0.990)	0.071*** (0.016)	0.002 (.017)	0.018 (0.027)
Union	0.112*** (0.019)	-0.001 (0.019)	-0.090*** (0.036)	0.095*** (0.037)	0.001 (0.038)	-0.044 (0.042)	-0.008 (0.041)	0.064 (0.051)	0.060 (0.058)	0.052*** (0.004)	0.027*** (0.004)	-0.036*** (0.007)
R&D	0.038 (0.0525)	0.007 (0.053)	0.051 (0.109)	0.138 (0.153)	0.190 (0.160)	0.123 (0.172)	-0.196 (0.274)	-0.882*** (0.345)	-0.731** (0.403)	0.058*** (0.014)	0.0196 (0.015)	0.009 (0.027)
NewInv	-0.030 (0.030)	-0.016 (0.0316)	0.005 (0.071)	-0.046 (0.083)	-0.066 (0.089)	0.215* (0.114)	-0.037 (0.060)	0.042 (0.075)	0.063 (0.088)	0.011 (0.012)	-0.007 (0.013)	0.073** (0.024)
Intgood	0.031 (0.029)	0.044 (0.029)	-0.015 (0.065)	-0.114 (0.085)	-0.022 (0.097)	-0.019 (0.114)	-0.026 (0.049)	0.017 (0.061)	0.032 (0.071)	0.009 (0.014)	-0.005 (0.015)	-0.0119 (0.027)
Age	0.009 (0.018)	0.038** (0.016)	0.031 (0.028)	-0.070 (0.047)	0.034 (0.046)	0.046 (0.039)	-0.061* (0.033)	0.043 (.036)	0.067* (0.041)	0.007 (0.006)	0.052*** (0.005)	-0.005 (0.008)
AcctSoft	0.014 (0.022)	0.033 (0.023)	-0.083 (0.052)	-0.065 (0.064)	-0.007 (0.071)	-0.072 (0.089)	-0.106** (0.052)	-0.105 (0.066)	-0.038 (0.077)	0.002 (0.007)	0.013 (0.008)	-0.015 (0.015)
AdmComp	0.027 (0.019)	-0.013 (0.020)	0.031 (0.046)	0.026 (0.049)	-0.025 (0.054)	-0.013 (0.063)	0.063 (0.040)	0.045 (0.053)	0.003 (0.062)	0.010 (0.006)	0.001 (0.007)	0.008 (0.013)
ProdTech	0.014 (0.017)	0.032* (0.018)	0.057 (0.041)	0.034 (0.047)	0.046 (0.052)	0.083 (0.064)	-0.028 (0.039)	0.003 (0.050)	0.031 (0.058)	0.018 (0.006)	0.024*** (0.006)	-0.016 (0.012)
Constant	-1.194 (0.104)	0.638 (0.098)	1.9828 (0.184)	-0.242 (0.267)	0.316 (0.263)	0.820 (0.256)	- 0.930*** (0.198)	-0.452 (0.224)	0.463 (0.237)	-1.032*** (.034)	0.516 (0.034)	2.037 (0.051)
R^2	0.706	0.404	0.101	0.535	0.474	0.063	0.759	0.426	0.343	0.728	0.333	0.142
Hausman statistic (χ^2)	294.34***	22.98**	18.84	48.46***	24.27**	5.02	52.18***	13.16	15.31	2075.19***	351.82***	89.13***
Breusch-Pagan statistic (χ^2)	822.04	622.14***	133.47***	160.30***	89.02***	54.09	83.26***	135.59***	86.94***	7329.03***	4723.83***	1953.61***
No. of Obs.	2000	1875	1551	327	302	267	329	310	279	14804	14185	12926

Note: The standard errors of the estimated coefficients have been given in the parentheses. Equations also include Time Dummy for years 1997 and 1998.
***Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Intgood has caused extensive skill-biased technological change effects in mining, accommodation, cafés, & restaurants industries causing relatively less unskilled employment by firms in these industries. In this case, the technological change indicator *Intgood* is to be considered extensive skill-biased since it reduces firm specific relative unskilled employment as well as average wages. This situation further explains the fact that the firms change their skill mix towards skilled workers in anticipation of introducing advanced technology in these industries.

AcctSoft has failed to show any significant impact on wages in all but one industry. In mining sector *AcctSoft* exerts significant negative impact on wages, significant positive impact on employment, and insignificant but positive impact on the skilled-unskilled employment ratio. Hence, the technological change via this variable has caused weak but extensive skill-biased technological change effects in mining industry firms. In manufacturing sector *AcctSoft* has significant negative effect on skilled-unskilled employment ratio and insignificant but positive effects on wages and employment. This exerts evidence of some intensive skill-biased technological change via *AcctSoft* in manufacturing. In wholesale trade industry *AcctSoft* has negative impact on all the dependent variables (significant only for employment) showing weak evidence of intensive skill-biased technological change.

The estimated coefficient of *AdmComp* has significant positive impact on employment of firms in wholesale trade industry. In finance & insurance sector, *AdmComp* has significant positive effect on skilled-unskilled employment ratio. Hence, administrative computer systems (*AdmComp*) could be said to have caused extensive skill-biased technological change in this sector by increasing relative demand for skills. In other sectors, the variable *AdmCom* does not show any significant effect on unskilled employment.

The estimated coefficients of *ProdTech* fail to show any significant effect on employment, wages, and skilled-unskilled employment ratio in most of the sectors. The exceptions are property & business and the combined sectors. In these two, *ProdTech* has significant positive effects on wages.

The effects of technological change on wages and employment could possibly be determined with greater precision if some variables on computer usage by the firms could be incorporated into the regression equations. To explore this hypothesis, a whole set of wage and employment equations has been run for firms in each industry (as well as for all firms combined) for the year 1996-97, with four variables on computer usage by firms[15] added to all the existing independent variables in equations (5.8'), (5.9'), and (5.10').

The OLS estimates of the new set of equations that include the computer usage variables as mentioned above have been reported in Table 5.6. The robust standard errors have been reported in parentheses. Most of the results remain similar to those in the random effect panel regression for the common variables (used in the random effects model and OLS model). Note that when the computer usage variables have been included as the technological change indicators, the common technological change variables show more significant effects on wages and employment of firms in different sectors, but not when firms in all sectors have been combined.

R&DIntens has caused skill-biased technological change that reduces the relative unskilled employment in manufacturing, cultural & recreational and in personal & other services firms. This is revealed by the significant negative and positive impacts of *R&DIntens* on skilled-unskilled employment and total employment of firms in these industries, respectively (Table 5.6). In some other sectors there have been evidences of extensive skill-biased technological change but none of the relevant effects are statistically significant. *R&D* dummy provides significant evidence of extensive skill-biased technological change recorded by firms in transport & storage, finance & insurance and personal & other services sectors. In the latter two industries there has been a fall in total employment due to increased *R&D*. Table 5.6 also shows that the variable *NewInv* generates mixed effects on firms in different sectors. While *NewInv* seems to lower relative unskilled employment in retail trade, transport & storage, property & business and personal & other services; *NewInv* increases relative unskilled employment of firms in accommodation, cafés, & restaurants and cultural & recreational sectors. *Intgood* exhibits significant and positive impact on skill

[15] These computer usage variables have been defined with brief descriptions in Table 5.A2 in appendix A5.II.

mix on firms in transport & storage industry only (Table 5.6). Except for a few sectors, the technological change indicators *AcctSoft*, *AdmComp*, and *ProdTech* do not seem to have significant effect on firms' wages, employment and on skill mix. The results presented in Table 5.6 also show that the three different computer use indicator variables, viz., *ComBus*, *ComLong*, and *NetAcc* have mixed and mostly insignificant effects on both employment and wages. In the manufacturing industry, which is relatively low-skill intensive sector (apparent from Table 5.1) compared to the services sectors the average wage goes down with the use of computers by the firms (*ComBus*). In manufacturing industry, if the firms use computer for a longer period of time (*ComLong*), then average wage is expected to rise significantly. The effects of these two variables (*ComBus* & *ComLong*) on employment in manufacturing firms are positive but only the effect of *ComBus* remains significant (Table 5.6). Note that the effects of these two computer usage variables on skilled-unskilled employment ratio have been negative and insignificant in manufacturing industry. But the effects on wages of ComBus and ComLong are significantly negative and positive, respectively, in manufacturing. Hence, there has been no significant evidence of intensive-skill-biased technological change on employment occurring via these two variables in the manufacturing firms of Australia. *ComBus* has significant negative effect on skilled-unskilled employment ratio of firms in mining, accommodation, cafes, & restaurants and cultural & recreational services sectors as well as in all sectors combined. The effects of *ComBus* on employment and wages in the firms in these industries have been mixed. These results indicate that the technological change via *ComBus* have been mixed in these sectors. On the other hand, *ComLong* has significant positive effect on skilled-unskilled employment ratio in firms in mining, accommodation, cafes, & restaurants, property & business industries as well as in all sectors combined. In these industries, *ComLong* has positive and mostly significant effect on average employment of firms. These results imply that in *ComLong* has caused significant demand shift for skilled workers in firms of the above mentioned industries.

Table 5.6 also reveals that the computer usage intensity variable, (CompR), which measures the number of employees using computers relative to the total employment in each firm, has a significant positive effect on wages paid by firms in manufacturing, wholesale trade and personal & other services industries. *CompR* does not seem to possess any strong effect on the ratio of skilled-unskilled workers of firms in different sectors. Manufacturing is the only sector where *CompR* significantly raises the share of skilled workers in firms' total labour force. In fact, for manufacturing firms, the coefficient of *CompR* has been highly significant in all three equations (Table 5.6). Combining the three estimates reveal that increased use of computers significantly raises average wages but reduces employment and unskilled employment in the manufacturing firms. Implicit in this result is extensive skill-biased technological change occurring through *CompR* in the manufacturing firms. On the other hand, *CompR* caused weak but intensive skill-biased technological change effects in the high-skill intensive finance & insurance sector firms.

The above results are precisely what one would expect with technological advancement in unskilled-intensive and skill-intensive industries. The higher the number of employees use computer relative to total employment, the higher would be the average wages paid by the firms in low-skill intensive sectors. This is due to the fact that relatively high skilled workers use computers in low-skill intensive industries. With technological progress firms in low-skill intensive sectors are also expected to be more efficient and the relative use of unskilled workers by the firms would decline leaving a negative impact on employment. On the contrary, in high-skill intensive services sectors such as, finance & insurance, even the low-skilled workers (e.g., bank tellers) are expected to be able to use computers and hence, *CompR* may not have significant effect on the average wages or employment. Also, *CompR* may not reduce the relative unskilled employment of firms in these high-skill intensive sectors.

It is also seen from table 5.6 that *CompR* has significant and negative effect on employment of firms in most of individual sectors including in all industries combined. Hence, it is evident from these results that increased use of computer is likely to reduce demand for workers in almost all firms. *CompR* has positive (significant or insignificant) effects on wages of firms in many of the individual sectors including the combined sector. Also, for firms in most of the sectors, the effects of *CompR* on skilled-unskilled employment ratio have been positive but not significant.

The results presented in Table 5.6 with regard to other independent variables are also similar to those obtained from the panel regressions. The union density shows negative impact on skill-unskilled employment ratio in most of the sectors (Table 5.6). This implies that relative shares of skilled workers in various firms increase with declining unionisation.

In this chapter, the effects of a wide range of technological change indicators on the Australian labour market have been examined. So far, the results show that there has been considerable diversity in the nature and magnitude of effects of these technological change indicators on firm specific labour force, wages, and skilled-unskilled employment ratios. A further interest would be to look into the impact of all these variables together or as a subset of these variables on the labour market. To this connection, effects of linear combinations of coefficients on dependent variables have been estimated for both the Random Effects panel regression models and the OLS regression models for the year 1997 only. The results of these joint effects of coefficients[16] on the labour market in the RE regressions have been presented in Table 5.7.

[16] This is also a test of joint effects of linear combinations of coefficients on dependent variable.

Table 5.6: Estimated Coefficients (OLS) of Technological Change on log of Employment, Wages and Skilled-Unskilled Employment Ratio, 1996-97

	Mining			**Manufacturing**			**Construction**			**Wholesale Trade**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	**lnEmpl**	**lnWage**	**SkUnskEmp**	**lnEmpl**	**lnWage**	**SkUnskEmp**	**lnEmpl**	**lnWage**	**SkUnskEmp**	**lnEmpl**	**lnWage**	**SkUnskEmp**
LnSale	0.227**	0.200*	-0.170	0.599 ***	0.245***	-0.152***	0.319***	0.460***	-0.210*	0.390***	0.283***	-0.457***
	(0.099)	(0.101)	(0.157)	(0.031)	(0.026)	(0.015)	(0.048)	(0.084)	(0.119)	(0.027)	(0.040)	(0.081)
R&DIntens	6.535***	-63.790*	5.752	1.103***	0.017	-0.592***	-30.201***	39.049*	12.943	2.404	-0.749	-2.613
	(1.218)	(34.504)	(3.961)	(0.315)	(0.313)	(0.153)	(8.103)	(11.309)	(13.837)	(2.245)	(2.944)	(2.842)
ExpShare	0.438	0.124	-0.111	-0.339***	0.112	0.116**	0.261	0.935**	-0.303	-1.155***	0.412	-0.073
	(0.472)	(0.482)	(0.547)	(0.123)	(0.100)	0.049	(0.626)	(0.424)	(4.290)	(0.235)	(0.274)	(0.285)
Union	0.050	0.079	0.007	0.158***	-0.110***	0.071***	0.043	0.080	-0.130***	0.051	0.004	-0.159***
	(0.103)	(0.072)	(0.095)	(0.014)	(0.015)	(0.006)	(0.039)	(0.070)	(0.051)	(0.054)	(0.028)	(0.062)
R&D	0.453	0.437	0.099	0.003	0.237***	0.027	1.171***	-0.644	-0.298	-0.077	0.545	-0.311
	(0.484)	(0.412)	(0.648)	(0.082)	(0.088)	(0.031)	(0.365)	(0.409)	(0.547)	(0.233)	(0.337)	(0.218)
NewInv	2.147***	-1.536***	1.056	0.060	-0.200***	-0.027	0.088	0.602*	0.801	0.001	-0.133	0.099
	(0.526)	(0.580)	(1.094)	(0.073)	(0.079)	(0.031)	(0.245)	(0.363	(0.601)	(0.113)	(0.220)	(0.189)
Intgood	0.071	1.013*	-1.603	0.057	-0.140**	-0.046	0.416***	0.268	-0.074	0.138	0.062	-0.076
	(0.243)	(0.457)	(1.101)	(0.059)	(0.066)	(0.029)	(0.123)	(0.293)	(0.325)	(0.094)	(0.128)	(0.219)
Age	0.137	0.583*	-1.090**	0.003	0.066*	0.025	0.050	0.051	-0.050	0.027	0.158***	0.010
	(0.105)	(0.300)	(0.531)	(0.038)	(0.039)	(0.018)	(0.039)	(0.089)	(0.101)	(0.031)	(0.048)	(0.068)
AcctSoft	0.255	-0.288	0.040	-0.042	0.209**	0.013	-0.266	0.369	0.001	-0.141	0.186	0.267
	(0.594)	(0.368)	(0.448)	(0.091)	(0.088)	(0.039)	(0.273)	(0.334)	(0.288)	(0.094)	(0.157)	(0.243)
AdmComp	0.513	-0.069	0.057	0.141	-0.102	-0.056*	0.186	-0.281	-0.484	0.228***	-0.237	-0.253
	(0.414)	(0.319)	(0.427)	(0.083)	(0.084)	(0.034)	(0.284)	(0.328)	(0.408)	(0.089)	(0.169)	(0.246)
ProdTech	-0.027	-0.142	0.714***	0.013	0.046	0.019	0.195	-0.108	-1.008**	0.087	-0.421	0.337
	(0.244)	(0.202)	(0.232)	(0.064)	(0.060)	(0.025)	(0.321)	(0.280)	(0.456)	(0.150)	(0.366)	(0.405)
ComBus	0.627	2.777	-7.223**	0.333*	-0.418***	-0.123	0.003	0.273	-0.294	0.136	-0.220	-0.340
	(0.613)	(1.885)	(3.390)	(0.193)	(0.131)	(0.112)	(0.197)	(0.345)	(0.402)	(0.132)	(0.238)	(0.328)
ComLong	-0.074	-0.761	1.916*	0.048	0.107***	-0.017	0.027	-0.016	-0.148	0.020	-0.014	0.171
	(0.241)	(0.584)	(0.982)	(0.057)	(0.041)	(0.029)	(0.078)	(0.137)	(0.128)	(0.054)	(0.098)	(0.129)
NetAcc	-0.162	-0.158	0.546	0.090	-0.083	0.014	-0.04	-0.315	0.401	0.023	-0.028	0.302
	(0.518)	(0.385)	(0.466)	(0.066)	(0.061)	(0.027)	(0.196)	(0.459)	(0.287)	(0.077)	(0.118)	(0.188)
CompR	-1.208*	0.289	0.461	-0.494***	0.358***	0.168***	-0.466***	-0.082	-0.493	-0.199***	0.518***	-0.033
	(0.622)	(0.525)	(0.704)	(0.084)	(0.072)	(0.042)	(0.149)	(0.373)	(0.325)	(0.083)	(0.148)	(0.222)
Constant	-0.302	-0.979	7.190**	-2.514***	1.473***	1.214***	-0.792***	-0.764	2.960***	-1.115***	0.172	4.549***
	(0.515)	(1.807)	(2.953)	(0.225)	(0.231)	(0.103)	(0.253)	(0.579)	(0.823)	(0.191)	(0.323	(0.685)
R^2	0.758	0.588	0.636	0.846	0.401	0.610	0.437	0.344	0.201	0.645	0.487	0.347
No. of Observations	49	48	45	1173	1162	1175	289	260	214	716	699	667

Note: Weighted regressions have been run (weights provided by ABS for BLS database). The robust standard errors of the estimated coefficients have been given in parentheses.
*** Significant at 1% level. **Significant at 5% level. *Significant at 10% level.

Table 5.6: Estimated Coefficients (OLS) of Technological Change on log of Employment, Wages and Skilled-Unskilled Employment Ratio, 1996-97 (Contd.)

	Retail Trade			**Accommodation, Cafes & Restaurants**			**Transport & Storage**			**Finance & Insurance**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**
LnSale	0.392*** (0.027)	0.310*** (0.042)	-0.183*** (0.074)	0.564*** (0.042)	0.513*** (0.057)	-0.237** (0.119)	0.513*** (0.062)	0.229*** (0.075)	-0.452*** (0.138)	0.361*** (0.046)	0.327*** (0.074)	-0.117** (0.053)
R&DIntens	0.589 (5.112)	4.617 (8.590)	-4.745 (6.541)	3.167 (3.103)	2.363 (3.648)	3.554 (5.977)	92.007 (130.607)	101.065 (86.563)	1.854 (134.143)	0.369 (0.480)	46.996*** (13.300)	-5.854 (12.389)
ExpShare	-0.168 (0.143)	0.134*** (0.215)	-0.301 (0.440)	-4.851** (2.223)	5.106 (3.073)	3.482 (4.368)	-0.085 (0.431)	-0.087 (0.306)	0.256 (0.573)	1.987 (1.667)	1.340** (1.668)	2.683 (2.426)
Union	0.113*** (0.045)	0.028 (0.058)	-0.202*** (0.050)	0.007 (0.043)	-0.026 (0.049)	0.039 (0.082)	-0.049 (0.040)	0.207*** (0.080)	-0.027 (0.079)	-0.106 (0.123)	0.144*** (0.055)	-0.331** (0.121)
R&D	-0.024 (0.133)	0.304 (0.238)	0.691 (0.456)	0.016 (0.331)	-0.618*** (0.333)	-0.797 (0.604)	0.619** (0.282)	-1.005*** (0.253)	1.361*** (0.500)	-0.152 (0.337)	-1.206*** (0.414)	0.980* (0.553)
NewInv	0.008 (0.121)	-0.078 (0.185)	-0.388** (0.146)	-0.011 (0.195)	-0.316 (0.319)	0.448* (0.267)	0.446*** (0.165)	-0.149 (0.233)	-0.695* (0.373)	0.074 (0.214)	0.219 (0.222)	0.319 (0.305)
Intgood	0.055 (0.085)	-0.220 (0.161)	0.081 (0.236)	0.059 (0.131)	-0.193 (0.132)	0.026 (0.206)	0.265 (0.209)	-0.041 (0.217)	1.503* (0.778)	0.208 (0.208)	-0.335 (0.263)	-0.122 (0.274)
Age	-0.0004 (0.030)	0.054 (0.064)	0.033 (0.085)	-0.012 (0.038)	0.139*** (0.044)	-0.188 (0.124)	0.018 (0.062)	0.123 (0.094)	-0.159 (0.167)	0.006 (0.073)	0.077 (0.079)	-0.063 (0.103)
AcctSoft	-0.007 (0.084)	-0.172 (0.230)	0.116 (0.370)	-0.319 (0.199)	0.251 (0.226)	-0.139 (0.244)	-0.173 (0.219)	0.338 (0.227)	-0.162 (0.422)	-0.076 (0.229)	0.343 (0.290)	0.228 (0.289)
AdmComp	0.074 (0.116)	0.481** (0.236)	-0.066 (0.264)	0.176 (0.189)	-0.109 (0.215)	0.272 (0.233)	-0.038 (0.279)	-0.448 (0.245)	-0.063 (0.411)	0.499*** (0.192)	0.012 (0.191)	0.300 (0.299)
ProdTech	0.635*** (0.153)	-0.285 (0.266)	-0.197 (0.206)	0.430 (0.397)	0.047 (0.400)	-0.312 (0.359)	0.494*** (0.171)	0.008 (0.207)	-0.655* (0.351)	-0.427* (0.224)	-0.078 (0.322)	-0.539 (0.491)
ComBus	0.144 (0.135)	0.00009 (0.243)	-0.364 (0.320)	0.653*** (0.163)	0.0008 (0.184)	-1.057** (0.457)	-0.074 (0.310)	0.964*** (0.371)	-0.835 (0.665)	0.405 (0.368)	-0.233 (0.387)	0.857 (0.693)
ComLong	0.040 (0.050)	0.088 (0.083)	0.020 (0.137)	-0.133* (0.072)	-0.002 (0.082)	0.244* (0.143)	0.124 (0.106)	-0.164 (0.153)	0.070 (0.171)	-0.069 (0.112)	-0.076 (0.129)	-0.028 (0.173)
NetAcc	0.080 (0.093)	-0.231 (0.152)	-0.228 (0.148)	0.089 (0.164)	0.181 (0.126)	0.251 (0.168)	0.069 (0.171)	0.016 (0.201)	-0.172 (0.276)	0.21 (0.123)	0.228 (0.204)	0.032 (0.210)
CompR	-0.234*** (0.085)	-0.020 (0.148)	0.093 (0.172)	-0.558*** (0.203)	0.306 (0.350)	0.226 (0.282)	-0.701*** (0.207)	0.344 (0.239)	-0.574 (0.388)	-0.0009 (0.154)	0.181 (0.224)	-0.166 (0.281)
Constant	-1.138*** (0.211)	0.201 (0.329)	2.573*** (0.547)	-1.567*** (0.293)	-1.158*** (0.398)	2.897*** (1.110)	-1.403*** (0.339)	-0.079 (0.473)	5.023*** (0.915)	-0.999*** (0.356)	0.861 (0.466)	1.582*** (0.446)
R^2	0.560	0.277	0.121	0.731	0.611	0.236	0.663	0.443	0.556	0.525	0.379	0.296
No. of Observations	511	498	470	190	182	174	185	177	162	163	151	118

Note: Weighted regressions have been run (weights provided by ABS for BLS database). The robust standard errors of the estimated coefficients have been given in parentheses.
***Significant at 1% level. ** Significant at 5% level. *Significant at 10% level.

Table 5.6: Estimated Coefficients (OLS) of Technological Change on log of Employment, Wages, and Skilled-Unskilled Employment Ratio, 1996-97 (Contd.)

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sectors		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Variables	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**	**lnEmpl**	**lnWage**	**SkUnsk**
LnSale	0.440***	0.356***	-0.385***	0.291***	0.328***	-0.014	0.596***	0.537***	-0.156	0.401***	0.312***	-0.248***
	(0.044)	(0.061)	(0.089)	(0.086)	(0.047)	(0.036)	(0.085)	(0.123)	(0.105)	(0.013)	(0.022)	(0.032)
R&DIntens	-0.146	0.289	0.440	7.904*	-11.763	-12.262***	376.410***	-19.208	-518.462***	-0.032	0.017	1.241
	(0.544)	(0.329)	(0.451)	(5.281)	(7.794)	(3.959)	(119.377)	(219.322)	(168.268)	(0.033)	(0.041)	(1.153)
ExpShare	0.113	-1.264*	0.087	-0.593	-0.115	0.379**	-1.140	4.557***	1.246**	-0.295	-0.0005	0.164
	(0.235)	(0.715)	(0.797)	(0.351)	(0.519)	(0.155	(0.865)	(1.045)	(0.592)	(0.187)	(0.135)	(0.164)
Union	0.237***	-0.089	0.009	-0.002	0.115	-0.022	-0.021	0.105	-0.061*	0.086***	0.064**	-0.076***
	(0.054)	(0.085)	(0.066)	(0.060)	(0.115)	(0.040)	(0.035)	(0.069)	(0.043)	(0.024)	(0.029)	(0.024)
R&D	-0.128	0.025	-0.173	1.450***	0.490	-0.173	-1.276**	-0.280*	3.308***	0.086	0.061	-0.062
	(0.332)	(0.229)	(0.414)	(0.283)	(0.687)	(0.248)	(0.624)	(0.968)	(0.941)	(0.124)	(0.132)	(0.148)
NewInv	-0.161	0.272	-0.601**	-0.086	0.379	1.091***	0.399	0.028	-0.661*	0.014	0.022	0.006
	(0.187)	(0.187)	(0.275)	(0.344)	(0.526)	(0.431)	(0.242)	(0.310)	(0.406)	(0.071)	(0.010)	(0.156)
Intgood	-0.030	0.102	0.525	-0.285*	0.962***	-0.059	-0.320	-0.351	0.175	0.085*	0.012	0.205
	(0.163)	(0.192)	(0.361)	(0.208)	(0.316)	(0.083)	(0.280)	(0.570)	(0.440)	(0.047)	(0.074)	(0.137)
Age	0.076*	-0.079	-0.072	-0.019	0.101	-0.009	-0.108	0.014	0.046	0.009	0.063**	-0.040
	(0.047)	(0.089)	(0.093)	(0.093)	(0.096)	(0.053)	(0.074)	(0.094)	(0.093)	(0.015)	(0.029)	(0.036)
AcctSoft	0.224**	-0.394	-0.479**	-0.450	0.164	-0.341	0.067	-0.750**	0.153	-0.036	-0.110	-0.006
	(0.101)	(0.208)	(0.248)	(0.417)	(0.450)	(0.341)	(0.235)	(0.366)	(0.195)	(0.075)	(0.109)	(0.140)
AdmComp	0.140	-0.105	-0.002	0.524*	-0.065	-0.028	-0.269	0.115	1.147**	0.225***	0.045	-0.054
	(0.133)	(0.227)	(0.346)	(0.292)	(0.374)	(0.098)	(0.317)	(0.420)	(0.510)	(0.071)	(0.118)	(0.162)
ProdTech	0.224*	-0.227	0.134	-0.518	-0.820	0.745*	0.460*	0.565	-1.138**	0.209***	-0.246	-0.174
	(0.126)	(0.231)	(0.340)	(0.397)	(0.550)	(0.425)	(0.247)	(0.549)	(0.500)	(0.062)	(0.112)	(0.137)
ComBus	0.760***	-0.376	-0.420	0.153	-0.413	-0.365***	0.210	-0.385	-0.005	0.235***	0.098	-0.610***
	(0.230)	(0.491)	(0.463)	(0.373)	(0.415)	(0.153)	(0.275)	(0.351)	(0.314)	(0.072)	(0.125)	(0.160)
ComLong	-0.186***	0.293**	0.343**	0.188	0.158	0.00004	-0.157	-0.064	0.086	-0.004	0.103**	0.174***
	(0.072)	(0.130)	(0.152)	(0.142)	(0.158)	(0.059)	(0.154)	(0.200)	(0.219)	(0.028)	(0.046)	(0.057)
NetAcc	0.248***	-0.119	0.200	0.288	-0.156	-0.181	0.007	-0.036	-0.337	0.120***	-0.057	0.024
	(0.081)	(0.187)	(0.247)	(0.293)	(0.223)	(0.152)	(0.280)	(0.282)	(0.223)	(0.049)	(0.079)	(0.095)
CompR	-0.367***	0.296*	-0.070	-1.112***	0.604***	0.248	-0.236	0.582**	-0.087	-0.384***	0.386	0.090
	(0.128)	(0.165)	(0.203)	(0.288)	(0.212)	(0.155)	(0.151)	(0.202)	(0.219)	(0.049)	(0.090)	(0.097)
Constant	-1.779***	0.822	3.197***	0.192	-0.478	0.760**	-1.274***	-0.407	1.373***	-1.092***	-0.146	2.902***
	(0.237)	(0.479)	(0.674)	(0.514)	(0.529)	(0.350)	(0.450)	(0.742)	(0.442)	(0.081)	(0.151)	(0.259)
R^2	0.604	0.386	0.214	0.617	0.650	0.412	0.572	0.474	0.245	0.574	0.321	0.125
No. of Observations	663	623	507	105	98	86	110	103	93	4901	4668	4267

Note: Weighted regressions have been run (weights provided by ABS for BLS database). The robust standard errors of the estimated coefficients have been given in parentheses.
***Significant at 1% level.. **Significant at 5% level. *Significant at 10% level.

In Table 5.7, the test results for the linear combination of the full set of the explanatory variables have been presented in the first row followed by results for a subset of linear combination of technological indicators that exclude the other variables from the full set. The third row presents results for a linear combination of technological variables comprising *AcctSoft, AdmCom,* and *ProdTech* only. As the table shows, the full set of technological change variables has significant positive and negative effects on employment and wages of firms in a few industries. However, the joint effect of these variables on skilled-unskilled ratio is not significant for firms in any of the industries. The results for the sub set of the technological indicators provide weak evidence of extensive skill-biased technological change for firms in construction, accommodation, café, & restaurants and personal & other services sectors (Table 5.7). This is implied by the test results that indicate that in most of the sectors, the joint impacts of these variables on employment and wages are either positive or negative and the impact on skilled-unskilled employment ratio is always positive though insignificant. The results also show that when all firms are combined, the technological change variables together have a positive and significant effect on employment and wages and positive but insignificant effect on skilled-unskilled employment ratio in the combined sector. These results imply that the technological change variables together have caused insignificant but extensive skill-biased technological changes in the firms of the combined sector.

The test results of the OLS regressions have been presented in Table 5.8. The table shows that the effects of all the explanatory variables on firm specific employment, wage, and skilled-unskilled employment ratio have been mainly insignificant in most of the sectors. These variables together have positive and significant effect on employment of firms in mining, manufacturing, cultural, & recreational services, personal & other services sectors and in the combined sector. All the explanatory variables have negative and significant effect on employment in construction firms. Also, as the table shows, the joint effects of these variables on wages paid by firms have been positive and significant in construction, finance, & insurance industries; and negative and significant in mining. However, the effects of these variables on skilled-unskilled employment ratios are significant and negative in manufacturing, cultural, & recreational services and personal & other services.

Hence, it appears that all the factors may not have jointly affected the relative unskilled employment of firms in these three sectors.

In the Table 5.8 it can also be seen that the tests for the combined effects of the subset of explanatory variables (that exclude R&D intensity and *R&D* dummy) fail to provide any significant evidence of intensive or extensive skill-biased technological change in firms in most of the sectors except for retail trade, cultural & recreational services and in all industries in general (combined sector). In retail trade and in combined sector, the subset of explanatory variables has significant positive effect on employment and significant negative impact on skilled-unskilled employment ratios of firms. This implies that growth in all technological factors does not adversely affect the relative unskilled employment of firms. In cultural & recreational sector the subset of explanatory variables (except *R&DIntens* and *R&D*) seems to have significant negative effect on employment and insignificant positive effect on skilled-unskilled employment of various firms (Table 5.8). This result indicates the presence of weak extensive skill-biased technological change effects on firm specific employment in cultural & recreational industries.

Table 5.7: Test Results of the Effects of the Linear Combination of All or a Set of Technological Change Variables of the RE Panel Regression Estimations, 1995-96 to 1997-98

	Mining			Manufacturing			Construction			Wholesale Trade		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ Age+AcctSoft+AdmComp+ ProdTech+TimeD97+TimeD98	+	+***	-	+***	+***	+	+	-	+	+	+	-
R&DIintens+R&D+NewInv+ Intgood+AcctSoft+AdmComp+ ProdTech	+	+***	_	+*	+***	_	-	-	+	+	+	-
AcctSoft+AdmComp+ProdTech	+**	-	+	+	+	-**	-	+	+	+	+	+
	Retail Trade			**Accommodation, Cafés & Restaurants**			**Transport & Storage**			**Finance & Insurance**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnsk**	**InEmpl**	**InWage**	**SkUnsk**	**InEmpl**	**InWage**	**SkUnsk**	**InEmpl**	**InWage**	**SkUnsk**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ Age+AcctSoft+AdmComp+ ProdTech+TimeD97+TimeD98	-	+*	-	+	+**	-	-	-	-	+*	-**	-
R&DIintens+R&D+NewInv+ Intgood+AcctSoft+AdmComp+ ProdTech	-	+	-	+***	+***	+	-	-	-	+	-**	-
AcctSoft+AdmComp+ProdTech	+	+	-*	+*	+***	-**	+	+**	-	+	+	+

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

Table 5.7: Test Results of the Effects of the Linear Combination of All or a Set of Technological Change Variables of the RE Panel Regression Estimations, 1995-96 to 1997-98 (Continued)

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sector		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ Age+AcctSoft+AdmComp+ ProdTech+TimeD97+TimeD98	+***	+***	-	+***	+*	+	+	+*	+	+***	+***	-
R&DIintens+R&D+NewInv+ Intgood+AcctSoft+AdmComp+ ProdTech	+***	+***	-	+***	+**	-	+	+*	+	+***	+***	+
AcctSoft+AdmComp+ProdTech	+***	+***	+	-	+	-	-*	-	-	+***	+***	-*

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

The variables *ComLong* and *CompR* together provide evidence of extensive skill-biased technological change in the overall sector. This is revealed by the highly significant & negative joint effects of these variables on employment, highly significant & positive effect on wages and significant (at 1 per cent level) and positive impact of these variables on skilled-unskilled employment ratios (Table 5.8)[17]. While *CompR* individually or all the technological change indicators together only give insignificant evidence of extensive skill-biased technological changes and hence, pose insignificant adverse effects on unskilled employment; the variables *ComLong* and *CompR* jointly provide evidence of significant extensive skill-biased technological change and hence, negative impacts on relative unskilled employment by firms in overall sectors.

This chapter examines the separate and joint effects of various technological change indicators on firm specific employment, average wages, and skill-unskilled employment ratio in different industries of Australia. One novelty of the approach adopted in this study has been by distinguishing technological change sourced from different activities and practices of firms with regard to knowledge development and enhancement of operative efficiency. A major emphasis has been assigned to identify whether technological changes are intensive skill-biased or extensive skill-biased and hence, whether technological change poses any negative impact on the unskilled employment of firms in different sectors. The main findings of this study suggest that the effects of technological change indicators vary by sector and also by type of the technological change indicators. It was found that technological change indicator such as R&D intensity mainly increased employment and wages of firms in most of the sectors without significantly reducing unskilled employment.

[17] This result has been presented only for the combined sector in Table 5.8. Other sets of technological change variables have been tested for their impacts on the labour market. The results have not been presented as they show mainly insignificant impacts on the labour market.

Table 5.8: Test Results of the Effects of the Linear Combination of All or a Set of Technological Change Variables of the OLS Regression Estimations, 1997-98

	Mining			**Manufacturing**			**Construction**			**Wholesale Trade**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ AcctSoft+AdmComp+ProdTech+ ComBus+ComLong+NetAcc+ CompR	+***	-*	+	+***	+	-***	-***	+***	+	+	-	-
LnSale +ExpShare+ Union+ NewInv+Intgood+ AcctSoft+AdmComp+ProdTech+ ComBus+ComLong+NetAcc+ CompR	+**	+	-	+	-	-	+	+	-	+	-	+
AcctSoft+AdmComp+ProdTech	+***	-*	+	+**	+	-***	+	-	-**	+	-	+
ComBus+ComLong+NetAcc+ CompR	-	+	-*	-	-	+	-**	-	-	-	+	+
	Retail Trade			**Accommodation, Cafés & Restaurants**			**Transport & Storage**			**Finance & Insurance**		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ AcctSoft+AdmComp+ProdTech	+	+	-	+	+	+	+	+	+	+	+***	-
LnSale+ExpShare+ Union+NewInv+Intgood+ AcctSoft+AdmComp+ProdTech	+***	-	-***	+	+	-	+	+*	-	+	+	+
AcctSoft+AdmComp+ProdTech	+***	+	-	+	+	-	+	-	-	-	+	-
ComBus+ComLong+NetAcc+ CompR	+	-	-*	+	+	-	-**	+**	-**	+	+	+

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

Table 5.8: Test Results of the Effects of the Linear Combination of All or a Set of Technological Change Variables of the OLS Regression Estimations, 1997-98 (Contd.)

	Property & Business			Cultural & Recreational Services			Personal & Other Services			Combined Sector		
	Dependent Variables			Dependent Variables			Dependent Variables			Dependent Variables		
Linear Combination of Variables	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**	**InEmpl**	**InWage**	**SkUnskEmp**
LnSale+R&DIntens+ExpShare+ Union+R&D+NewInv+Intgood+ AcctSoft+AdmComp+ProdTech+ ComBus+ComLong+NetAcc+ CompR	+	+	-	+*	-	-***	+***	-	-***	+***	+	+
LnSale +ExpShare+ Union+ NewInv+Intgood+ AcctSoft+AdmComp+ProdTech+ ComBus+ComLong+NetAcc+ CompR	+***	-	-	-***	+	+**	+	-	-	+***	+	-*
AcctSoft+AdmComp+ProdTech	+***	-***	-	-	-**	+	+	-	+	+***	-**	-
ComBus+ComLong+NetAcc+ CompR	+**	+	-	-	+	-	-	+	-	-	+***	-**
ComLong+CompR										-***	+***	+***

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level.

On the other hand, technological change indicators such as computer use or introduction of new advanced products etc. adversely affected total employment and notably, the unskilled workers in various sectors. Further scrutiny revealed that the technological change indicators reduced unskilled employment mainly in the low-skill intensive sectors. There was no evidence that computer use or increased use of advanced products or services reduced unskilled employment of firms in high skill intensive services sectors.

The findings of this study are consistent with those of some others conducted on the relationship between wage and employment growth and technological change in the Australian labour markets (e.g., Gretton, et al., 2002). There have been a large number of studies in the U.S. that support the hypothesis that technological change is responsible for the widening of wage differentials by skill level of the workers (Bound and Johnson, 1992; Katz and Murphy, 1992; Juhn, Murphy and Pierce, 1993). Berman, Bound and Griliches (1994) showed that despite the increased return to skills, there has been evidence of increased share of non-production workers in U.S. manufacturing. Later on, Berman, Bound and Machin (1998) extended Berman, Bound and Griliches's (1994) study by including other developed countries and found that skill-biased technological change induced increase in shares of non-production workers in the developed countries. In another study, Allen (2001) found that technological change and relative wages of workers with different schooling were largely related with each other over the period 1979 to 1989 in the U.S.

5.5 Conclusions

Within/Between Industry Decompositions

In this chapter *within* and *between* industry components of shifts in skill demand have been calculated for two-digit manufacturing industries. Higher *within* industry effects have been recorded by all but two industries. The only industry that saw a small reduction in the skill composition is Food, Beverages and Tobacco industry. Non-Metallic Mineral Product and Printing, Publishing & Recorded Media industries experienced higher *between* industry effects. These higher b*etween* industry effects imply that in these two industries, increase in international trade has primarily caused shift in labour demand from unskilled intensive firms to skill-intensive firms. On the contrary, higher *within* industry effects recorded by all other industries indicate that in these industries, skill-biased technological change shifted the skill composition of labour demand.

This chapter also examines the determinants of average wages and employment in Australian firms over a selected period in the 1990s marked by increased IT capital deepening strategies initiated in Australian economy and sustained reduction in trade barriers. A number of technological change indicators have been used that are believed to have some impact on the labour market. In this chapter, the effects of the technological change indicators have been analysed by controlling for the effects of openness and labour institutions on labour market conditions. In addition to examining the relationship between technological change indicators and labour market while exploring evidence of skill-biased technological change, this study also provides some insights on the type of skill-biased technological change (i.e. intensive or extensive).

Estimates of Random Effects panel regression show strong effects of R&D intensity on wages and employment of firms in many of the industries while controlling for export intensity, unionisation, and age of the business. It is interesting to note that technological change via R&D intensity alone does not pose significant negative impact on the unskilled employment. *R&D* dummy shows some significant intensive skill-biased technological change effects in the personal & other services sector firms. In contrast, *R&D* indicates extensive skill-biased technological change effects on firms in the finance & insurance sector. In this study, R&D intensity, and *R&D* dummy show stronger effects on the labour market than other technological change indicators, which are similar to Allen's (2001) findings for the U.S. labour market. The variables to control for the effects of trade liberalisation (ExpShare), labour institutions (Union) and age of firms (Age) have significant effects on the wages and on employment of firms in many of the sectors.

Another important result is that the computer usage intensity variable (CompR) provides evidence of extensive skill-biased technological change effects on unskilled employment of firms in low-skill intensive sectors such as manufacturing. On the other hand, in the high skill-intensive services sector such as finance & insurance, *CompR* does not show any significant effect on employment, wages, or skilled-unskilled employment ratio of various firms. In other sectors *CompR* has significant negative impact on employment and positive (both significant and insignificant) effect on wages paid by firms. Except for manufacturing firms, *CompR* has insignificant positive effect on skilled-unskilled employment ratio in six industries thereby providing weak evidence of extensive skill-biased technological change effects in these sectors.

While testing the impacts of all or set of technological change variables on employment, wage, and skilled-unskilled employment ratio, the results are still similar. For example, all the technological change variables have weak evidence of extensive skill-biased technological change impacts on firms in the combined sector. This result implies that while technological change indicators are not strong enough to affect the unskilled workers of firms in different individual industries, they seem to reduce unskilled employment of firms in all sectors combined.

In this study, an especial emphasis has been placed on different technological change indicators, such as, R&D intensity, introduction of new services, increased administrative computer system usage, and other softwares in the panel regression over the period 1995-96 to 1997-98. Information on computer use by firms has been used for the year 1996-97 only. More robust set of empirical results might have been obtained if the information on computer use were also available and used for the other years. Another weakness of the data used in this study is that the BLS database contains information of only those firms that have less than 200 employees and thus represents smaller businesses in Australia. The results have been obtained for a shorter period of time and more dynamic effects may differ from the results of this study or may show more significant relations by sector. Also, due to lack of data availability, the effects of technological change on skilled-unskilled wage ratio could not be examined in this study.

Despite the above limitations, a key contribution of this study is that it provides evidence of different technological change indicators that have effects on the Australian labour market controlling for increased export intensity, unionisation, and age of firms. These controlled variables themselves have strong and divergent effects on the labour market by sector. The impacts of technological change indicators differ in type and also in magnitude from sector to sector. This study finds that firms in mainly low-skill intensive industries experienced more extensive skill-biased technological change effects.

Chapter Six

Conclusions and Policy Recommendations

Recent changes in the world order with globalisation, regional integration, and technological progress significantly prompted global competitions and catching up of the backward nations along the development ladder. At the same time, such processes have had considerable impacts on the global factor markets, especially on the labour market. One perceived impact has been in the form of rising and declining relative wages of skilled and unskilled workers, respectively. Such changed structure has increased wage differential and employment ratio of skilled and unskilled workers. Especially for the developed economies, the decrease in wage of unskilled labour compared to the skilled labour in real terms over the last decades has become even more apparent. As researchers tried to delve into more precise underlying reasons of such rising wage inequality, they identified growing international trade and technological change as the two most likely factors responsible for rising skilled-unskilled wage gap or increasing unemployment of unskilled workers. The issue further generated lively debate between the labour and trade economists since the late 1970's and to date there is yet to be a consensus as to whether one or the other of the two above-mentioned factors could be the major force working behind rising skilled-unskilled wage gap and employment gap across the developed countries.

Australia is among the few developed economies that significantly complied with the GATT and WTO policies in recent decades with reduced tariff on wide variety of products traded internationally. In the 1990s, Australian economy saw a significant improvement in productivity growth marked by substantial growth in technology. A major proportion of such growth was contributed by the Australian manufacturing industries that experienced considerable reduction in protection since the end of 1980s. More liberalized market conditions, increased competitions and productivity growth brought about significant changes in structure of Australia's labour market with higher demand and pay for the skilled workforce. This thesis investigated into the key evidence, causes, and consequences of rising wage differential between skilled and unskilled workers and increased skilled demand in Australian manufacturing and in some other industries.

A major focus of this thesis has been to review the relevant issues from a macroeconomic to microeconomic perspective by examining evidences at the macro to firm level establishments in different industries. Based on a more comprehensive examination of empirical data and range of analytical models, this study contributes by providing more conclusive evidence about the causes and consequences of skilled-unskilled wage inequality and increased skilled demand in Australia. Significant implications for policy emanate from the results of this study that could be used for Australian economy as well as its manufacturing and other sub sectors.

6.1 Summary of the Main Findings

This study adopts three major analytical perspectives. Firstly, factor biased technological change has been tested as an explanatory factor for rising wage inequality in Australia. Secondly, effect of international trade on the wage inequality has been examined in Australian manufacturing. Thirdly, the relationship between technological change and labour market is further explored using evidence from the establishments of various sub sectors of Australian economy.

The results of Chapter Three provides evidence of skill-biased technological change to have the some impact on economy wide skilled-unskilled wages compared to the other two factor-augmenting technological changes after fulfilling some assumptions. The sensitivity analysis shows that if the assumptions, that were also found in different studies to be existing in different economies, were violated then skill-biased technological change falls below the other two factor-augmenting technological changes in affecting the skilled-unskilled wage ratio in Australia over the concerned period. The findings from this chapter also points to the fact that only skill-biased technological change cannot explain most of the observed skilled-unskilled wage inequality and there have been other factors affecting the rising wage inequality in Australia. These results are in line with the findings of other studies (Fallon and Layard, 1975, Krusell, Ohanion, Ríos-Rull and Violante, 1997) which conclude that the skill-biased technological change with the capital-skill complementarity may explain the rising returns to skill with increased supply of skills, rather than a fall in the return to skills.

To examine the existence of S-S effects in Australia the relative consumer and producer prices have been compared in Chapter Four and trend of relative skilled-unskilled wages has been analysed. Counterfactual measurement of trade has been used as a more formal approach of measuring the effects of import penetration on employment in Australia. Further, to examine nature of trade (i.e. whether trade has been intra or inter industry), G-L indices have been measured for Australia's trade with its 52 major trading partners involving eight different three and four-digit manufacturing industries for the year 1995. Australia's wage ratios with foreign countries in each industry, size of various economies, exchange rates, and distances of various trading partner countries from Australia have also been examined as explanatory variables for the trade patterns.

This study finds that significant structural changes of exports and imports in Australia have taken place after the beginning of sustained reduction of tariff and non-tariff barriers accorded to all manufacturing industries since the late 1980's. There have been mixed evidences with regard to the presence of Stolper-Samuelson effects in Australian manufacturing. Over the period following trade liberalization, strong S-S effects have been found for some unskilled labour intensive industries, such as clothing, motor vehicles and food, beverages & tobacco and footwear. However, in most of the other manufacturing sub sectors in Australia, trade could not explain the shifts in labour market movements. The counterfactual trade effects show some significant relationship between actual changes in the Australian labour market and the counterfactual changes for the unskilled workers. Positive and significant correlation was observed between the counterfactual trade effects on the changes in unskilled employment and actual unskilled employment over the period 1986 to 1996. The counterfactual trade effects failed to explain most of the movements of the skilled employment in Australia. These results indicate that some other causes must have been also at work behind the rising wage inequality and shifts in labour demand in Australian economy other than trade. It has also been identified from the analysis of Australian trade pattern and effects on labour market in eight different three and four-digit manufacturing industries that so far, in most of these manufacturing industries in Australia, increased trade with low-wage countries did not result in any significant net job losses according to the skill intensity of production or shifts in wage distribution among workers of different skill levels. The results further suggested that Australian trade with high wage countries is mostly intra-industry in nature, especially involving high skill-intensive sectors. It has been found that Australia's increased trade with developing countries has, so far, not impoverished the unskilled workers significantly in these industries. However, industries such as, computer and footwear, have been adversely affected by trade with low wage countries, as Australia's trade in these sub sectors has been heavily inter-industry in nature with these countries. For products such as heavy machineries, medicinal & pharmaceuticals, no significant trade pattern has been detected with countries based on their income status. Also, no significant relationship has been identified between intra-industry index for Australian total trade and the income status of the trading partners, even after controlling for distance, exchange rate, size of economies, and scale of openness with those countries.

The results of this study are comparable to the findings of other studies done in Australia by Fahrer and Pease (1994), Murtough et al. (1998) and Karunaratne (1999). Using different methods, they found mixed evidences for different manufacturing industries in Australia. Their studies also suggested that international trade affects the unskilled intensive sectors significantly but most of the other industries fail to show any significant effect of increased trade on overall employment. Studies on U.S. also present mixed evidences of trade effect on the labour market (Lawrence and Slaughter, 1993; Sachs and Shatz, 1994).

In Chapter Five, to measure the existence of skill-biased technological change and its effects on shifts in skill demand in Australia, the overall shift of skilled employment in the two-digit manufacturing industries has been decomposed into *within* and *between* components for the period of 1995-96 to 1997-98. Empirical evidence from *within* and *between* industry decomposition reveals that from 1995 to 1998, skilled workers in total manufacturing employment increased by 5.111 percent of which 4.049 percent change in skilled workers has been due to *within* industry changes and 1.062 percent has been attributable to *between* industry changes. This implies that 79.22 percent of total change was due to *within* industry skill upgrading and remaining 20.78 percent owed to other factors such as trade. Most of the industries experienced an increase in the skill composition *within* the industry except for Food, Beverages, and Tobacco that underwent a small reduction in the skill composition. The industries that experienced greater *between* industry effects included Non-Metallic Mineral Product and Printing, Publishing & Recorded Media. The *between* industry effects in these two industries imply that increased international trade has been primarily causing the shifts of the demand for labour from unskilled intensive industries to skill-intensive industries. Higher *within* industry components in the other industries imply that the skill-biased technological change has shifted the skill composition of labour demand *within* the industries.

These results of *within* and *between* industry shifts in skilled demand of this study are also conformable with findings of other studies on Australia. Borland and Foo (1996) reported that the predominant influence on changes in the share of production (unskilled) employment in Australian manufacturing, for three different periods, viz., 1952-1968, 1969-1977, and 1978-1987, has been the changes *within*. Berman, Bound and Machin (1998) found that in Australia bulk of skill upgrading has occurred *within* rather than *between* industries over two different periods, viz., 1970-1980, and 1980-1990.

In Chapter Five, using firm level data from the BLS, three separate equations have been estimated to examine the effects of range of firm specific technological change indicators, namely, share of R&D expenses to total sales, different technological advancement and change dummies etc. on the three dependent variables, i.e., log of firm specific employment, log of average real wages and skilled-unskilled employment ratios. The relationships have been estimated after controlling for factors such as log of total sales, share of exports in total sales, proportion of trade union members, and age of the firms. The equations have been estimated in a random effect panel regression framework.

This study identifies strong effects of R&D intensity on wages and on employment in most of the sectors while controlling for export intensity, unionisation, and age of the business. Technological change via R&D intensity and R&D dummy did not show any significant negative impact on the labour market. The variables to control for the effects of trade liberalisation (ExpShare), labour institutions (Union), and age of firms (Age) showed significant impact on the wages and on employment in many of the sectors. The technological change indicator *NewInv* has caused weak extensive-skill-biased technological change in few sectors but has caused significant unskilled job losses both in cultural & recreational and in combined sector, which can be viewed from the significant positive impact of *NewInv* on skill mix in these two sectors. *Intgood* has extensive skill-biased technological change impacts in mining, accommodation, cafés, & restaurants sectors causing relatively less unskilled workers employed by firms in these two industries. It has caused intensive skill-biased technological change in finance & insurance sector. *AdmComp* has significant positive impact on employment in wholesale trade sector. In finance & insurance sector, *AdmComp* has significant positive effect on skilled-unskilled employment ratio. Hence, *AdmComp* has caused extensive skill-biased technological change in this sector by increasing relative demand for skills. In other sectors, this variable does not show any significant negative effect on unskilled employment.

In chapter five, in a set of separate OLS regressions computer use variables have been used as technological change indicators along with other above mentioned technological change indicators for only 1997. In OLS regressions, *R&DIntens* has caused intensive skill-biased technological change in manufacturing, cultural & recreational and in personal & other sectors, while the effect in manufacturing is weak (because the effect on wages is positive in manufacturing). In some other sectors there have been evidence of extensive skill-biased technological change via *R&DIntens* but none of these effects have been statistically significant. *R&D* dummy has shown significant evidence of extensive skill-biased technological change in firms of transport & storage, finance & insurance and personal & other services sectors and reduced employment in two out of these three sectors. *NewInv* seems to lower relative unskilled employment in retail trade, transport & storage, property & business and personal & other sectors. In accommodation, cafés, & restaurants and cultural & recreational sectors *NewInv* increased relative unskilled employment. *Intgood* has significant and positive impact on skilled employment only on firms in transport & storage industry. *AcctSoft*, *AdmComp*, and *ProdTech* technological change indicators do not have any significant impact in

most of the sectors (except few) on any of the dependent variables while used in the OLS regression analysis along with computer use variables.
The results of the OLS regressions also show that the three different computer use indicator variables, *ComBus*, *Comlong,* and *NetAcc* have mixed and mostly insignificant effects on both employment and wages. *ComBus* has significant negative effect on skilled-unskilled employment ratio of firms in mining, accommodation, cafes, & restaurants and cultural & recreational services sectors as well as in the combined sectors. The effects of *ComBus* on employment in the firms in these industries have not been significant but positive. These results state that the technological changes via *ComBus* have not reduced the unskilled employment. On the other hand, *ComLong* has significant positive effect on skilled-unskilled employment ratio in mining, accommodation, cafes, & restaurants, property, & business and also in combined sectors. This variable has positive and mostly significant association with employment in these sectors. These results imply that *ComLong* has caused significant extensive skill-biased technological change in the above mentioned sectors and has increased relative demand for skilled workers of the firms in these sectors.

CompR does not seem to possess any strong effect on the skill mix of firms in different sectors. The only sector where this variable has significantly increased the skill share in employment is the manufacturing. In fact, in the manufacturing sector it has caused extensive skill-biased technological change and increased relative demand for skills significantly. For the rest of the sectors as well as for the combined sector, the relationships between *CompR* and skilled-unskilled employment ratio have not been significant. The effects of *CompR* on employment have been significant and negative in most of the sectors as well as in the combined sector stating the fact that use of computer by increased proportion of employees is causing reduced employment in firms in most of the industries. Only so far, its effects on skill mix have mostly been positive but insignificant in most industries. One exception is the high-skill intensive finance & insurance sector, where *CompR* has insignificant but negative impacts on skilled-unskilled employment ratio.

To find the effects of a group of technological change variables, tests have been performed both in the Random Effects Panel regressions as well as in OLS regressions for the year 1997. In the RE panel regressions, all the technological change indicators together present weak evidence of extensive skill-biased technological changes in construction, accommodation, café, & restaurants, personal & other services sectors as well as in the combined sector. . In other sectors the effects of all technological change variables together failed to provide any significant evidence of intensive or extensive skill-biased effects on employment of the firms.

In the OLS regressions for the year 1997, tests for the combined effects of all the technological change indicators together (except R&D intensity and R&D dummy) fail to provide any significant evidence of intensive or extensive skill-biased technological change on firms in most of the sectors except for retail trade, cultural & recreational services industries and in combined sectors. In retail trade and in combined sector, these technological change variables have not reduced the relative unskilled employment. In cultural & recreational sector the same variables have caused extensive skill-biased technological change by reducing the unskilled employment by firms.

In OLS regressions, the effects of all technological change variables on employment, wages, and skilled-unskilled employment ratio have mainly been insignificant in most of the sectors. But in manufacturing, cultural, & recreational services and personal & other services sectors these variables together have significant negative impact on skill mix and on wages. *Comlong* and *CompR* together provide evidence of significant extensive skill-biased technological change effects on firms in overall sector. Whereas, *CompR* individually or all the technological change indicators together (except *R&DIntens* and *R&D*) only give insignificant evidence of extensive skill-biased technological change effects and hence, pose insignificant threat to the reduction of unskilled employment.

The results of this study are consistent with those of other studies conducted on the relationship between wage and employment growth and technological change in the Australian labour market (e.g., Gretton et al., 2002). There have been a large number of studies in the U.S. that support the hypothesis that technological change is responsible for the widening of wage differentials by skill level of the workers (Bound and Johnson, 1992; Katz and Murphy, 1992; Juhn, Murphy and Pierce, 1993). Berman, Bound and

Griliches (1994) showed that despite the increased return to skills, there has been evidence of increased share of non-production workers in U.S. manufacturing. Berman, Bound and Machin (1998) extended this study for other developed countries and found that skill-biased technological change induced increase in shares of non-production workers in those countries. Allen (2001) found that in the U.S., technological change and relative wages of workers with different schooling were largely related with each other over the period 1979 to 1989.

6.2 Policy Implications

Based on the major findings of the present research, a number of policies could be recommended. It has been devised that unskilled labour augmenting technological change does not match with the actual situation of wage inequality in Australia. However, skill augmenting technological change in Australia provides better explanation for wage inequality. Therefore, a major implication for policy emerges from these results. One strategy for the government could be to identify the sectors and sub-sectors that warrant for skill augmenting technological change, account for the relative loss of jobs and reduced relative real wages for the unskilled workforce in those sectors, and arrange appropriate skill building (e.g., education & training) and job replacement programmes for the unskilled workers.

It has also been detected that for most of the sectors, international trade so far has not worsen the skilled-unskilled wage inequality in Australia. Hence, greater involvement in trade with developing countries due to globalisation should not be a matter of concern for the policymakers in Australia who aim at a more equitable and welfare augmenting labour market reform. The skilled-unskilled wage gap has been found to be affected with increased trade with developing countries only in a few unskilled labour intensive manufacturing industries such as textile, clothing, footwear & leather, motor vehicles and other manufacturing. Since Australia has already heavily embarked on trade liberalisation in these industries, through phased reduction of tariff since the end of 1980's, skilled-unskilled wage inequality has been expected to rise further in these industries. Hence, it would be more appropriate for the government to ensure job replacement for the retrenched unskilled workers in these industries and impose more progressive taxation on the income of the skilled workers to deter further worsening of skilled-unskilled wage inequality. But progressive taxation on the income of the skilled workers raises two major problems. First, the market rewards workers for their skills or productivity. This is the most efficient mechanism. Government interference would only distort the pricing mechanism. To remedy this problem there should be proper cost-benefit analysis before government intervention in the market. Second, a worker would not be encouraged to invest in human capital if the worker believes that he will be taxed for this investment. Again, to remedy this problem the rate of taxation on skills should be determined in such a way that the worker would still invest in human capital and the wage differential will not widen further. Increased trade barriers are not recommended as reduced trade would cause reduction in overall economic and welfare situation. Increased trade barriers are also expected to result in retaliations by the trading partners especially when the developing countries have been getting economically stronger and are able to negotiate with developed countries better than ever before.

Australia's trade with developing countries in computer & computer parts industry, which is expected to be highly skilled-intensive, has been found to be heavily inter-industry in nature. This implies that Australian involvement in increased trade of computer and computer parts with the low wage countries would cause significant distortions in Australian labour market by shifting skilled demand and skilled wages. As opposed to this, Australia's trade in these computer products industries with developed or high-income countries would not adversely affect Australian labour market in view of the new trade theory. There should not be much concern yet regarding trade with developing countries in this high-skill intensive sector due to the fact that Australia's trade in this sector is expected to be more with developed countries than with low-income developing countries. Although the key findings of this study indicate little evidence of trade effects on Australian labour market over the last two decades, it is not unlikely that Australia's increased trade with low wage countries, stimulated further by future trade liberalisation, would cause larger adverse effects on Australian labour market by increasing wage inequality among the skilled and unskilled workers or by changing skill mix in the labour market. Hence, there seems to be an urgency of continued, as well as extended, policy support with a view to correct the increasing wage inequality and curb rising unemployment among the unskilled workers in Australia.

It was found that most of the manufacturing industry subdivisions experienced an increase in the skill composition *within* the industry in Australia. Almost 80 per cent of total change in entire manufacturing employment in Australia was due to *within* industry skill upgrading and the rest 20 per cent was due to some other factors such as trade. Policies are to be adopted so that with future increase in international trade and with technological progress unskilled workers in the manufacturing industries could be employed elsewhere with appropriate training to match the skill requirement.

A host of policy options also emanate from the estimated results of the wage, employment, and skilled-unskilled employment ratio equations. One implication is that increased proportion of R&D expenditure is expected to raise wages paid by firms in most of the industries. Since higher R&D expenditure would increase demand for skilled workers, such consequences should be noted as expected while planning public policy support. R&D intensity does not significantly affect employment levels in sectors such as mining, manufacturing, and wholesale trade. However, significant positive impact of R&D intensity on employment and wages in accommodation, cafes, & restaurants, property & business and cultural & recreational services sector firms implies that increased proportion of R&D expenditure would raise the average employment and wages. There is no evidence that relative unskilled employment would be reduced by increased R&D intensity by firms. Firms could be encouraged to enhance share of their R&D expenses for the growth of technology and efficiency and enhance their competitiveness.

It has been well pronounced in the empirical results that technological change, mainly via computer usage, reduces the relative unskilled employment of the firms in most of the sectors. To avoid rising wage inequality among the skilled and unskilled workers and also to avoid unskilled job losses, extensive and continuing training programmes for the unskilled workers should be introduced. It would help the low and unskilled workers to be more adaptable to the changed macroeconomic as well as international conditions. If proper government policies have not been adopted in Australia then today's small concerns about trade and technology effects on labour market can become large and out of control in future with more skill-biased technological change from the introduction of advanced technologies by the firms, especially in the unskilled-intensive sectors, as well as, with increased international trade especially with developing countries.

6.3 Limitations and Recommendations for Future Research

Despite the theoretical and empirical merits ascribable to this thesis for policy and practice, this study is not free from limitations. From published sources, it was difficult to obtain information on separate divisions of employment and wages for skilled and unskilled workers in Australia. The time series data used in this study is also subject to limitations due to change of definitions of ASCO categories as well as change of industrial classification scheme from ASIC to ANZSIC by ABS over the concerned periods. The analysis of trade effects on Australian manufacturing might contain some biases due to unavailability of a comprehensive trade database that resulted in the use of different data sources.

To examine the effect of firm specific factors and technological change indicators, this study considered a period from 1995-96 to 1997-98, the period of coverage under the BLS, with firm specific information on computer use variables available for the year 1996-97 only. It would be better if longitudinal information on computer use were available for the entire four year period. Also, the study included businesses employing less than 200 employees, as only for these firms information were available from BLS database with adequate industry classification details. Proxy measures for skilled and unskilled workers have been used in this study since the BLS database does not contain workforce classification on the basis of skills. Also, the number of methodologies commonly used to model relationship between technological change and wage inequality had to be truncated due to lack of any separate division of wages paid by firms to skilled and unskilled workers.

There are few possible avenues for future research suggestible on the basis of findings and limitations of this study. Subject to availability of Australian trade statistics in suitable detail, one could also consider finding the existence of Stolper-Samuelson effects and counterfactual trade effects on skilled and unskilled workers at a highly disaggregated industry level to analyse the impacts of increased trade on Australian labour force. Inclusion of some bigger firms and precise information on skilled-unskilled wage and employment might add newer dimensions to the firm level evidence on effect of technological change on Australian labour market. On theoretical ground, to examine the effects of different factor biased technological change, the use of flexible form translog function could also be recommended where degrees of freedom are adequate.

This study however, makes a substantial contribution to existing knowledge by revealing the relative effect of trade and technological change on skilled-unskilled wage inequality in Australian economy with a special emphasis provided on firm specific employment, wage and skilled-unskilled employment ratio responses to various operational and technological factors. The findings of this study do not only possess significant welfare implication for Australian economy and its labour market, but also provide important policy guidelines especially in situations of crucial decision-making where equity-efficiency trade-off is high. Recent and ongoing trade liberalisation, significant reductions in Australia's protectionist trade policies that resulted in a major surge of competitive pressures from overseas, technological change, and the issues of returns to skills in Australian work force that have been examined in this thesis, are of utmost importance for policy and practice. The findings of this thesis clearly reveal that there should be both static and dynamic policy avenues to achieve a more equitable wage distribution, increased employment with appropriate skill match, enhanced efficiency of the labour force and a sustainable balanced growth across various sectors in Australian economy. Achieving such targets would be of immense significance for Australia given the socio-economic challenges it has been facing in the integrated and liberalised world of the new millennium.

APPENDICES

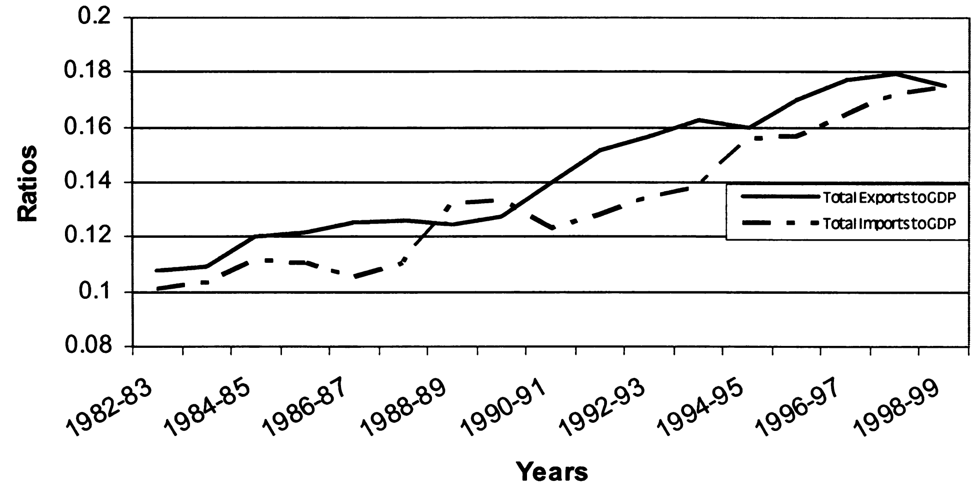
Appendix to Chapter Four: A4

Appendix: A4.I

Trend and Structural Change in Australian Trade

Figure 4.A1 shows increased openness of Australian economy to international competition over the past two decades. The figure shows the trends in the share of Australia's total exports and imports to GDP (in real terms) from 1982 to 1998. It is seen from the figure that the ratios of total exports and imports to GDP have been growing over time. The share of exports to GDP was 0.11 in 1982-83 and became 0.18 by 1998. The ratio of imports to GDP was 0.10 in 1982-83, which grew to 0.17 by 1998 (Figure 4.A1). With growing competition due to increased imports, production would decline in import competing sectors. However, production would increase in the export oriented sectors with reduced tariff on imports of inputs and with increased demand for exports. In order to examine the trend of growing shares of Australia's exports and imports to total GDP, it would be useful to estimate the average rates of growth of these shares over time. Also, structural change in Australia's trade pattern could be tested statistically.

Figure 4.A1 Ratio of Exports and Imports to GDP, 1982-83 to 1998-99



Source: Author's calculations using data from ABS Table 47 and DFAT (2000a).

To analyse the trends in shares of Australian exports and imports to GDP, two regression equations have been estimated. The dependent variables, e.g., share of exports to GDP and shares of imports to GDP have been regressed on time, t, over the period 1982-83 to 1998-99. The estimated equations are as follows,

$$Exp_t/GDP_t = \underset{(0.002)}{0.100} + \underset{(0.0002)}{0.005}\ Time \qquad (4.A.1)$$

$$R^2 = 0.958 \quad N = 17$$

and

$$Imp_t/GDP_t = \underset{(0.003)}{0.091} + \underset{(0.0003)}{0.005}\ Time \qquad (4.A.2)$$

$$R^2 = 0.924 \quad N = 17$$

From the above regression results, it could be seen that both the shares of exports and imports have significantly grown over time. The estimated coefficient of time is 0.005 for both the equations. From the above results (both the figure 4.A1 and the equations 4.A.1 and 4.A.2) it is not possible to test if the relative exports and imports to GDP of Australia have undergone any significant changes between the two periods. The periods are, the pre reform period from 1982-83 to 1989-90 (that is the period when the textiles and clothing as well as overall manufacturing sectors were enjoying high rates of protections) and post-reform period from 1990-91 to 1998-99 (that is the period when the protection given to all the sectors in manufacturing, including textiles and clothing, started to decline drastically). Also, if the relationships have changed, it is not possible to test from the above results whether the relative exports have changed more or less than the relative imports after the reform.

It would be interesting to observe if the relationships between trade ratio and time have changed between the two periods. To test for the possible structural changes in the volume of trade before and after the reduction in trade barriers the data on the ratio of exports and imports to GDP are divided into two periods, 1982-83 to 1989-90 and then 1990-91 to 1998-99 and a dummy variable approach has been used.[1]

[1] Dummy variable approach has been preferred to Chow test as the dummy variable approach would provide the test of structural changes both in intercepts and slopes of the ratio of exports and imports rather than only stating about the presence of structural change.

Pooling all the observations together (from 1982-83 to 1998-99) so that, t = 1, 2, .. 17, following regressions are estimated for ratio of exports and imports to GDP, separately.

$$(Exp_t/GDP_t) = \alpha + \alpha_1 D_t + \beta_1 \,Time + \beta_2 \,(D_t * Time)$$

$$(Imp_t/GDP_t) = \alpha + \alpha_1 D_t + \beta_1 Time + \beta_2 \,(D_t * Time) \qquad (4.A.3)$$

where, Exp_t , Imp_t and GDP_t are real exports, real imports and real GDP at time t, respectively, measured in 1989-90 constant prices. Time is the variable to capture the effects of time trend on the dependent variable. D_t is a dummy variable, where $D_t = 1$ for the observations in the pre-reform period (1982-83 to 1989-90) and Dt = 0 for observations in the post-reform period (1990-91 to 1998-99).

The estimated regression for relative exports equation is:

$$\begin{aligned} Exp_t/GDP_t = {} & 0.105 + 0.002\, D_t + 0.005\, Time - 0.002\, (D_t * Time) \\ & (0.009) \quad (0.009) \quad (0.001) \qquad (0.001) \qquad (4.A.4) \\ & R^2 = 0.978 \qquad N = 17 \end{aligned}$$

and the estimated regression for relative imports is:

$$\begin{aligned} Imp_t/GDP_t = {} & 0.060 + 0.034\, D_t + 0.007\, Time - 0.003\, (D_t * Time) \\ & (0.004) \quad (0.005) \quad (0.0003) \qquad (0.0009) \qquad (4.A.5) \\ & R^2 = 0.961 \qquad N = 17 \end{aligned}$$

The results show that Australian exports ratio to GDP has experienced significant (at 10 percent level) change after the trade liberalisation (pre-reform coefficient of Time is 0.002 and post reform coefficient is 0.005 and they are significantly different from each other). However, the intercepts of pre-reform and post-reform periods are not significantly different for the exports ratio equation. On the other hand, Australian imports ratio to GDP has experienced strong and significant (at 1 percent level) structural change after the trade reforms. The structural change occurred both in the intercept and coefficient of the time trend on imports ratio equation. Pre-reform import ratio regression has the intercept 0.094 (obtained as, 0.060+0.034) and coefficient 0.004 (which is, 0.007-0.003). The post-reform import ratio regression has the intercept of

0.060 and coefficient of 0.007 and these are significantly different from the corresponding intercept and coefficient of the pre-reform period. The information we get from these simple regressions states that the ratio of imports to GDP of Australia has increased significantly after the trade reform. The results also state that relative exports and imports to GDP have increased after the trade reform and the impacts of liberalisation are much higher on imports than on exports. This in turn, implies that the existence of S-S effects could be a likely factor in distorting Australian labour market.

Appendix: A4.II

Description of Factor Content of Trade Measurement

The final demand D_i is the real final demand for output in sector i, which can be met by domestic production Y_i^F and net imports, $N_i = M_i - X_i$. The final demand (real) can then be written in terms of domestic production (real) and net imports (real):

$$D_i = Y_i^F + N_i \tag{4.A.6}$$

Thus, the domestic product is: $Y_i^F = D_i - N_i$. (4.A.7)

The vector of domestic production used to meet the final demand is related to total domestic production by an input-output matrix **A**. Each element in the input-output matrix is the requirement of one product for the production of another including the possibility of using the same product as its input. A row of the input-output matrix **A** gives the unit amount of one product required to produce a unit of all other products. A column, on the other hand, shows how one product uses all other products as its input in its unit production. Thus, the total production can be written as

$$Y = (I-A)^{-1}\ Y^F \tag{4.A.8}$$

where, I is an identity matrix of the same order as matrix A and $^{-1}$ denotes the inverse of a matrix.

The *i*-th element of Y is the total production of sector i and the *i*-th element of Y^F is the amount of domestic production used to meet the final demand in sector i. From (4.A.6) it can be seen that the change in total production is a function of change in final demand and change in net imports in each sector. Using the input-output matrix to measure the direct and indirect effects, the change in total production would be:

$$\Delta Y = (I-A)^{-1}\ \Delta D - (I-A)^{-1}\ \Delta N \tag{4.A.9}$$

The problem here is that the final demand in each sector is unobservable and it is to be calculated indirectly from the total domestic production by using the input-output matrix assuming that it is invertible. Therefore,

$$Y^F = (I\text{-}A)\,Y$$

and, $$D = Y^F + N.$$

The next step is to construct the counterfactual change in employment. The base year ratio of net imports to final demand is:

$$n_i^{86} = N_i^{86} / D_i^{86} \qquad (4.A.10)$$

The counterfactual level of net imports for sector i in the current year, 1996, is defined as N_i^C. The counterfactual net import is measured by keeping the ratio of net imports to final demand fixed at the base year and then multiplying by the final demand in the current year. Hence, the counterfactual net imports is:

$$N_i^C = n_i^{86} * D_i^{96} \qquad (4.A.11)$$

Keeping the same level of final demand in 1996 the output effects are calculated with the counterfactual level of net imports rather than the actual net imports. Defining the difference between the counterfactual and actual net imports as $\Delta N_i^{96} = N_i^C - N_i^{96}$ and using equation (4.A.9) the change in total domestic production can be defined in terms of the difference among the counterfactual and actual net imports multiplied by the inverse of the input-output matrix.

$$\Delta Y^{96} = (I\text{-}A)^{-1}\,\Delta N^{96} \qquad (4.A.12)$$

The assumption behind the counterfactual trade effect measurement is that the average labour-productivity in 1996 of skilled and unskilled workers in each sector remains unaffected by the counterfactual. Therefore, percentage changes in skilled and unskilled employment are equal and the percentage change of skilled or unskilled employment is equal to the percentage change in output. We can write the relationships as:

$$\Delta L^{96} / L^{96} = \Delta Y^{96} / Y^{96} \qquad (4.A.13)$$

Multiplying this percentage changes by employment level of 1996 would give the counterfactual employment change in level:

$$(\Delta Y^{96} / Y^{96}) L^{96} = \Delta L^{96} \qquad (4.A.14)$$

Dividing this level change by 1986 employment in each sector and in each group would give the effects of trade on the rate of change of employment between 1986 and 1996:

$$\Delta L^{96} / L^{86} \qquad (4.A.15)$$

Appendix to Chapter Five: A5

Appendix A5.I

Indexes Used to Transform Nominal Terms to Real

Exports are deflated by the export price indexes of the relevant years, base of each index: 1989-90=100, obtained from ABS Catalogue No. 6405.0. Wages are transformed into real wages by dividing the wages of each year by the Consumer Price Indexes of the relevant years, base of each index: 1989-90=100, obtained from ABS time series, 2000. Research & Development spending and sales are transformed into real values by diving them by GDP deflator of the relevant years, base of each index: 1989-90=100, obtained from ABS time series 2000.

Appendix A5.II

Definitions of Variables

Table 5.A1

The definitions of the variables used in the study drawn from BLS-based database

Mnemonic	Definition	Range	Description
	Dependent Variables		
lnEmpl	Log of employment	Log level	Log of total full time employment by firm
lnWage	Log of average wages	Log level	Log of total wages & salaries divided by total employment by firm
Sk/Unsk	Skilled-Unskilled employment ratio	Ratio	Total skilled employment divided by total unskilled employment by firm

Explanatory Variables

lnSale	Log of real sales	Log level	Log of sales of goods & services by firm
RDIntens	Share of R&D expenditure	Ratio	R&D expenditure divided by sales by firm
ExpShare	Export share in sales	Ratio	Total exports divided by total sales by firm
Union	Estimated percentages of persons that were union members as at 30 June	1-6	1 if none 2 if up to 10% 3 if 11% to 25% 4 if 26% to 50% 5 if 51% to 75% 6 if 76% to 100%
R&D	If the firm performed or paid other to perform R&D	0-1	1 if yes, 0 otherwise
NewInv	If the firm introduced new services or products	0-1	1 if yes, 0 otherwise
Intgood	During the next three years if there is any intention to introduce new goods or services by firm	0-1	1 if yes, 0 otherwise
Age	Age of firm	1-5	1 if age is less than 2 yrs old 2 if 2 yrs to less than 5 yrs old 3 if 5 yrs to less than 10 yrs old 4 if 10 yrs to less than 20 yrs old 5 if 20 or more yrs old
AcctSoft	If there were any major increase in the use of accounting software since last year in the firm	0-1	1 if increased, 0 otherwise
AdmComp	If there were any	0-1	1 if increased, 0 otherwise

	major increase in the use of 'other administrative computer systems' since last year in the firm		
ProdTech	If there were any major increase in the use of production/service technology in the firm	0-1	1 if increased, 0 otherwise

Table 5.A2: Technology variables included in OLS estimation for 1996-97

Mnemonic	Definition	Range	Description
		Explanatory Variables	
ComBus	If the firm uses computers	0-1	1 if yes, 0 otherwise
ComLong	For how long has the firm been using computers	0-3	0 if not applicable 1 if less than 2 years 2 if 2 years to less than 5 yrs 3 if 5 or more years
EmpCom	The share of employees use a computer at least once a week by firm	Ratio	Number of employees use a computer at least once a week divided by total employment by firm
NetAcc	If the firm accesses internet	0-1	1 if yes, 0 otherwise
CompR	Share of employees using computer	Ratio	Employees use computer divided by total employment in each firm

Appendix A5.III

Panel Estimation and Choice of Random Effects Model

A simple panel regression model can be presented as:

$$Y_{it} = \beta_0 + \beta_1 X_{it1} + \ldots\ldots + \beta_k X_{itk} + a_i + u_{it} \qquad (5.A.1)$$

where, i is the number of observations (i = 1,2, .., n), t is the time period (t = 1,2, .., T) and k denotes the explanatory variables (k = 1,2, .., K). Y is the dependent and Xs are set of independent variables and a_i is the unobserved effect.

A Fixed effects model or a random effects model can be used to estimate a panel regression. The choice of either of the two models is important and it is done mainly based on the type of data used and their conformity with the assumptions of the two types of model. The differences between the assumptions of fixed and random effects models are discussed below along with a list of assumptions of random effects model (the first three assumptions are also the assumptions of fixed effects model).

i) For each t, the expected value of the error term, u_{it}, is zero: $E(u_{it}) = 0$.

ii) Variance of the error term is constant: $Var(u_{it}) = \sigma_u^2$ for all t.

iii) For all $t \neq s$, the errors are uncorrelated: $Cov(u_{it}, u_{is}) = 0$

iv) There is no perfect linear relationship among the explanatory variables.

v) The variance of a_i is constant: $Var(a_i) = \sigma_a^2$

and most importantly

vi) The expected value of the unobserved effect, a_i, is constant: $E(a_i) = \beta_0$.

The assumption (vi) is the assumption that rules out correlation between unobserved effect and the explanatory variables. This assumption also marks the key distinguishing feature between fixed effects and random effects models. In fixed effects (FE) models, it is assumed that the Xs are correlated with the unobserved effects and first differencing is used to eliminate a_i from the equation (5.A.1). In the random effects (RE) model, it is assumed that a_i is uncorrelated with each explanatory variable over the whole time period.

The fixed effects models might be viewed as applying only to the cross sectional units used in any study, not to any additional units outside the sample. For example, an inter-country comparison may include the full set of countries, for which the model can be viewed as constant and fixed effects model could be used for the estimation. For other settings, the individual specific constant terms might be viewed as randomly distributed across cross-sectional units. That is, this view would be appropriate if the sampled cross-sectional units were drawn from large population, as would be the case for the longitudinal data set (Greene, 2000). It has also been argued that the distinction between fixed and random effects models is an erroneous interpretation and the individual effects should always be treated as random (Mundlak, 1978). From practical point of view, the fixed effects approach is costly in terms of degrees of freedom lost. In a longitudinal data set, the random effects model has some intuitive appeal (Greene, 2000).

Comparisons of FE and RE estimates can be performed by Hausman (1978) specification test, which is used to test whether there is correlation between the a_i and X_{itj} (Wooldridge, 2003). The Hausman specification test states, under the hypothesis of no correlation between a_i and Xs, OLS in fixed effects and GLS in random effects are consistent, but OLS is inefficient. Hence, the null hypothesis states that the two estimates should not differ systematically, under the assumption of no correlation between a_i and Xs (Greene, 2000). If the null hypothesis could be rejected, there would be a question of unpleasant choice to make. One choice is to accept that the model is misspecified and the other choice is to hold the specification being correct, in which case the observed differences must be due to the zero-correlation between a_i and Xs (STATA, 1999).

Breusch and Pagan (1980) have devised a Lagrange multiplier (LM) test for the random effects model based on the OLS residuals. According to this test, the null and alternative hypotheses are:

$$H_0 : \sigma_a^2 = 0$$
$$H_1 : \sigma_a^2 \neq 0$$

That is, a test that Var (a_i) = 0. If Var (a_i) =0, meaning a_i is always 0, and equation (5.A.1) can be estimated by OLS directly (STATA, 1999). If the tests result in rejection of null hypothesis, the result is in favour of the alternative, that is, in favour of the random effects model.

In this chapter a choice was made between fixed and random effects panel estimators on the basis of the Hausman specification test and Breusch Pagan LM test. Gretton, Gali and Parham (2002) also preferred random effects to the fixed effects estimators while using BLS database for finding the ICT impacts in Australian economy in a growth accounting framework. They mentioned that, for the ICT variables, the explanatory power of variables would be reduced by the presence of a relatively large set of dummy variables included in the fixed effects. They also state that random effects model takes into account within and between firm variability and provides estimates with greater precision than fixed effect models for this specific data set.

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