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The Role of Technology in Determining Skilled Employment: An Economywide Approach

Staff Research Paper

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Contents

BOXES

FIGURES

TABLES

Acknowledgments

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1 Introduction

While the Australian economy has enjoyed strong growth and falling unemployment over much of the past decade, there has been concern over two emerging trends. The first is the perceived lack of growth in full-time employment opportunities and the second, the growing earnings inequality among those working. Family incomes, prior to taxes and transfers, have become more unequal over the past three decades in Australia. Between 1968-69 (the first year comprehensive surveys on income distribution were available) and 1997-98, the gap in incomes between families in the top 10 per cent of the income distribution and those in the bottom 10 per cent increased by over 30 per cent (Saunders 2001). Government taxes and transfers have offset a good deal of the increase in market income (Pappas 2000 and Saunders 1995).

Numerous studies of the Australian economy have linked increasing income inequality with a growing dispersion in the earnings between groups of workers. Most have focused on differentiating workers by skill level. Pappas (2000) and Borland and Wilkins (1996), for example, have shown that growing wage inequality among different skill levels is a driving force behind the growth in income inequality. This outcome is seen to be a result of changing relative demand for skilled workers (Borland 1998).

Academic literature proposes two explanations for the change in the relative demand for skilled workers. The first is that technological advances are biased in favour of the employment of skilled workers. These advances have driven up the demand for skilled workers, and hence their wages, by increasing their productivity relative to less skilled labour. This hypothesis is known as skill biased technical change (SBTC). Changes in employment patterns brought about by SBTC would see an increase in the relative employment of skilled workers. According to the SBTC hypothesis, this technical change is pervasive, of a form directly affecting most industries. This argument also implies that the wages of skilled workers would increase along with the demand.[1]

The second explanation is that the increasing access to foreign products and markets, or ‘globalisation’ of the world economy, has hurt less skilled workers in

[1] The actual change in the wages of skilled workers would depend on changes in supply. The effect of changes in supply are not explicitly considered in this paper.

Australia (and other developed countries). According to this hypothesis, imports from low wage countries have lowered demand for, and wages of, less skilled labour in the domestic economy. This stems from a reduction in the demand for these workers as the industries traditionally employing them are affected by increased openness to international trade. The price effect alone would lower the wages of less skilled workers. But, as these import-competing industries lower output and release less skilled workers, a change in the distribution of employment between industries would be observed. This explanation implies that the wages of these less skilled workers would fall, increasing their employment chances in other sectors of the economy. Relative employment shifts should then be observed between, rather than within, industries.

Figure 1.1 shows the relationship between the change in the ratio of the total hours worked per week by skilled labour to less skilled labour and the change in the relative (skilled/less skilled) hourly wage in Australia.[2,3]

The figure shows that for many sectors, both relative wages and relative total hours worked increased for skilled workers between 1987 and 1994. This outcome is consistent with the predictions of the SBTC hypothesis. However, four sectors: Community services (Csv), Transport and Storage (TrS), Recreational, personal and other services (RPO) and Wholesale/retail trade (WRT) experienced a decline in ratio of skilled to less skilled hours worked and an increase in the ratio of hourly wages. In one sector, Public Administration (Pub), skilled workers' relative hours increased while their relative hourly wage fell.

For the trade hypothesis to hold, the relative wages of less skilled workers should have fallen (ie, relative wages for skilled workers risen). This is observed for all but one sector — the public sector. The increase in the relative hours worked by less skilled workers in some sectors (ie, those not directly affected by imports) may be in response to this decline in relative wages. If the trade hypothesis holds, then less skilled workers released in traded sectors would depress the wage and encourage employment in other sectors. This may even lead to an increase in relative employment of less skilled workers, given the dynamics in the system of supply and

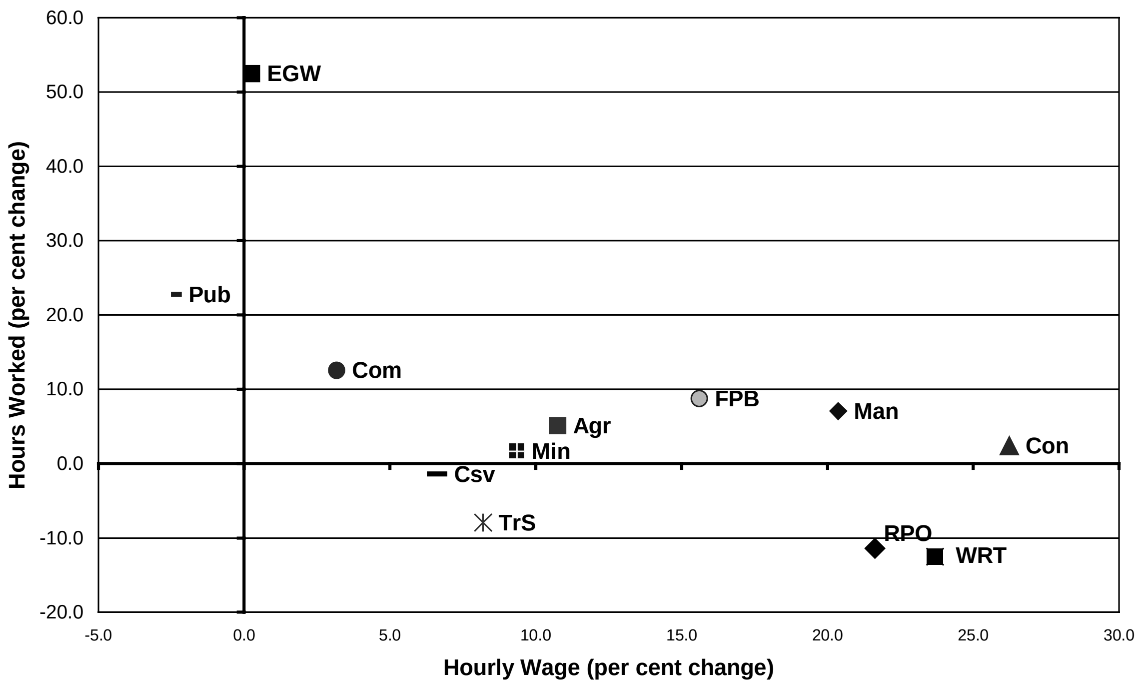
2 Throughout this report, 'skilled' labour is defined as workers classified in occupations 1-3 inclusive of the eight ABS ASCO1 occupational classifications. These are manager, professionals and para professionals. 'Less skilled' labour refers to occupations 4-8. These are trade persons, clerks, salespersons, plant and machinery operators and labourers.

3 The level of aggregation used to define 'skill' in this paper is quite high. Movements within the two broad labour categories are thus masked. This may affect the changes in relative employment and wages shown in figure 1.1. Differences observed in the ratio of skilled to less skilled hours worked or hourly wage may be due to the difference in the make up of each labour skill category in each sectors.

demand. This reduction in relative hours worked by skilled workers is observed in the four sectors noted above.

Figure 1.1 **Change in the ratio of skilled/less skilled labour, 1987–94[a]**

Percentage change in ratio



[a] The 12 sectors examined are Public Administration(Pub), Electricity, gas and water (EGW), Communications (Com), Mining (Min), Agriculture (Agr), Finance, property and business (FPB), Manufacturing (Man), Construction (Con), Community Services (Csv), Transport and storage (TrS), Recreational, personal and other services (RPO) and Wholesale and retail trade (WRT).

Data source: PC estimates based on ABS *Labour Force Survey*, August.

There are two alternative explanations that cast doubt on the trade interpretation of the relative increase in employment of less skilled workers in the four sectors. First, the level of aggregation presented here may be masking changes coming from individual industries within sectors. Previous research for Australia (de Laine, Laplagne and Stone 2000) has shown that the change in relative employment for these sectors comes from mostly changes within the sector, not between sectors. Changes within sectors have been shown to be associated with SBTC (de Laine et al. 2000 and Berman, Bound and Griliches 1994 for more details). The trade hypothesis implies that falling wages for less skilled workers would lead to improved job prospects in other sectors, indicating movement between sectors.

The second explanation could stem from a change in the nature of demand in the overall labour market. As noted above, much of the job growth in Australia has come in the form of part-time employment. While each of these four sectors increased its total employment between 1987 and 1994 (and indeed, over the past 20 years) most of this increase in demand was for part-time work.[4] Most part-time work is in less skilled occupations (Wooden 1998). Therefore, the decline in relative hours worked by skilled labour may be a reflection of the growth in part-time employment, and not a shift toward the use of less skilled workers, per se.[5] This could be interpreted as a technical effect (due to change in production methods) in these industries biased in favour of less skilled employment. This explanation is at odds, however, with the SBTC hypothesis which states technical change favours skilled workers.

1.1 Gaps in existing evidence

The relationship between technological change and the demand for skilled workers has been examined in both Australia (de Laine et al. 2000) and across the OECD (Autor et al. 1993, Berman et al. 1994, and Machin and Van Reenen 1998, to name a few). The general contention is that technological change is biased toward the employment of skilled workers and that changes in trade flows provide very little explanation for observed increases in skilled employment and wages relative to less skilled workers. However, the debate is not yet settled. There are still arguments made (eg Leamer 2000), that trade plays a distinct role and that relying on arguments based on the factor content of imports (such as examining less skilled labour intensive imports) is misguided when investigating this issue. Leamer argues that studies examining the effects of trade on employment based on the factor content bias of traded goods are not measuring the correct variables. Prices should be examined, and changes in factor prices, in basic standard, small country trade theory, can only come about from changes in product prices.

Krugman (2000) argues that the factor bias of technological change is of substance, except when dealing with a small open economy *and* when technical change occurs only in *that* economy. He goes on to say '…since the real situation does not meet either criterion, factor bias definitely does matter.' (p. 53).

[4] For example, between 1978 and 1997, total employment in the transport and storage sector increased 18 per cent. Full-time employment in that sector rose 13 per cent while part-time work rose 77 per cent.

[5] Thus, the increase observed here could be a function of the trend toward more part-time work, rather than Stolper-Samuelson-type effects implied by the trade hypothesis.

There are other issues with empirical work done to date that this study attempts to address. Haskel and Slaughter (2001) argue that many of the studies to date are limited. One reason is that the link between SBTC and relative wage changes is usually based on a single-sector model — ie manufacturing. In this framework, technical change *must* be factor-biased to affect relative wages. However, in a multisector model, the wage effects of technical change often depend on which sector experienced most technical change, independent of any factor bias. Thus, a multisector model provides a more balanced analysis of possible causes for changes in relative wages.

It is also important to examine types of technical change. The type of technical change — factor-biased or factor-neutral — will have different effects on relative wages. This is related to another criticism with regard to many current studies, that is, the measure of technical change (Chenells and Van Reenen 2000). Often technical change is measured by related but not conceptually identical variables such as the intensity of R&D spending or computer use. Improving this measure will enhance a model's ability to pick up potential sources of technical change.

Another common assumption in models used to investigate growing earnings inequality is that prices and technology are exogenous. In linking price changes with international trade, these studies assume, explicitly or implicitly, that these domestic price changes are due to trade forces. But as Deardorf and Haiku (1994) and Freeman (1995) have argued, evidence is required as to the degree to which domestic price variation is caused by international trade, such as through changes in trade barriers or changes in international product prices, versus domestic influences such as changes in tax policy.

It is reasonable to ask what forces are causing technical change. Increased openness itself can lead to increased technological change (Wood 1994). The trade hypothesis focuses on product and factor pricing pressure from imports. Even if this hypothesis is rejected, however, increasing openness to foreign trade may still have played a role in the changing demand for skilled employment. Secondary effects stemming from increases in competitive pressures and imported technologies may also influence a firm's choice of labour type. An investigation into either (or both) of the SBTC or trade explanations suffers in a partial equilibrium framework because indirect effects, flow-on effects, inter-industry linkages, and price responses cannot be comprehensively accounted for. This limitation is especially problematic if the two leading explanations are likely to be interrelated. For example, increased pressure from international competition can cause producers to adopt more technology-intensive production methods within the same industry (Haskel 1996) or in other sectors of the economy (Machin and Van Reenen 1998). Conversely, technology can stimulate trade. Dixon et al. (2000) show that technical change in such inputs as communication equipment, communication services, scientific equipment and computers is a strong driver of import and export growth in Australia between 1987 and 1994.

Overall, identifying the underlying forces that are driving wages and technology is important in understanding the consequences of policies such as lowering trade barriers or increasing R&D incentives. When trying to measure the effects of the economic reforms in Australia made during much of the 1980s and 1990s, understanding these forces seems particularly relevant.

In summary, there are four generally identified issues surrounding the investigation of growing earnings inequality in the literature to date.

1. It is necessary to consider sectoral changes in factor proportions (skilled to less skilled), both absolutely and relatively. This is hindered in a single sector or partial equilibrium analysis.
2. Types of technical change need to be distinguished, highlighting the inadequacies of traditional proxies.
3. Estimating technical change by setting prices and wages exogenously could provide biased results. The skill mix employed in an industry is likely to be associated with both high wages and high quality capital (as high quality capital may require highly skilled, highly paid labour). Thus, both wages and technology need to be modelled simultaneously.[6]
4. There is a potential interrelationship between openness and technical change. Thus, a measure of interaction between these two is needed.

This paper attempts to address some of these issues while providing additional evidence of SBTC for Australia. The object of this paper is to investigate the underlying sources of the shift in employment toward skilled workers in Australia, ie upskilling, using a general equilibrium framework. While the focus is on the role of technological change, the arguments for the trade hypothesis are also considered.

1.2 Benefits of general equilibrium analysis

Preliminary research for Australia (de Laine et al. 2000) has identified technical change as playing a major role in the increase of skilled relative to less skilled

[6] Krueger (1993) discusses this point, but it was not until Chennells and Van Reenen (1997) that it was specifically controlled for in estimation.

employment, especially since the mid-1980s. This finding is consistent with the international literature. However, this research has also detected a significant positive association between upskilling and exports. It suggests that this association is due to the increased technical sophistication required to remain competitive in traditional exports markets, and to capture new markets. In this context, the use of general equilibrium (GE) modelling is especially appropriate, as it allows the analyst to identify the drivers of upskilling by going beyond a simple bilateral association. In a GE framework, a series of linkages can be followed back to its origins. Thus, it becomes possible to investigate if the observed link between export orientation and upskilling is ultimately a product of technical change.

As technological change typically affects many industries, a partial equilibrium analysis of the SBTC argument is less than ideal. Research leading to technological improvements in one industry can often benefit other industries. These effects are known as 'spillovers' and can occur through, for instance, copying, reverse engineering, employee poaching or licensing. By requiring a direct measure of technology at each individual industry level, the partial equilibrium analysis underlying most SBTC literature only tells part of the story. Indeed, Machin and Van Reenen (1998, p. 1217) state that 'we cannot deduce the full effect of technology on labour market structure without also closing the model by looking at supply side effects and the non-manufacturing sector'.

Using a general equilibrium approach can also provide more specific measures of technical change. A general equilibrium model is a more fully specified model and reduces the number of 'rest of the economy doesn't change' assumptions made in a partial equilibrium approach. By expressly accounting for adjustments across the entire economy (according to the underlying theory of the model) to changes in certain factors, the resulting outcomes have much less 'noise'. This improves the efficiency of the variable measures. For example, the model allows for changes in the relative use of capital and labour to be distinct from those relating to changes in the use of different types of labour. It allows these changes to differ across parts of the economy as well as stages in the production process.[7]

In a computable general equilibrium (CGE) modelling framework, technical change can be measured in each industry through appropriately defined 'residual' variables that reflect shifts in demand and supply schedules.[8] Further, various forms of

[7] For example, technical change can be accounted for (and differ) in the raw materials stage (such as grain production), in the intermediate input stage (such as flour production) and in the final goods stage (such as bread production).

[8] Other such residuals are changes in consumer preferences and changes in domestic/import preferences. It should be pointed out that it is only the size of the residual that gets precisely measured in a CGE model. The interpretation of that residual is partly a matter of economic

technical change can be distinguished based on the nature of their bias (neutral, labour saving, capital saving etc) and the extent of their coverage (industry specific, factor specific, commodity specific etc).

Given the potential interrelationships between trade and SBTC, identifying the sources of the observed increases in employment and wage relativities becomes very difficult unless an economywide, GE approach is adopted. According to Tyers et al.

> General equilibrium methods avoid the problem of selective exogeneity and allow most of the proposed explanations to be examined in a consistent setting. Moreover, they offer ready answers to counterfactual questions such as: how great would the labour market changes have been in the absence of trade liberalisation? And, hence, they are an aid in the decomposition of those changes. (1999, p. 243):

Put another way, the GE approach is able to examine various sources of change simultaneously, which makes it a particularly useful technique.

The advantages of the GE approach have resulted, in recent years, in the growing use of CGE modelling to investigate the sources of widening wage relativities between skilled and less skilled workers. Tyers and Yang (1997, 2000) have used the GTAP model to simulate the effects of trade liberalisation and technical change on relative wages for selected groups of countries. Similarly, Jean and Bontout (2000) have investigated the sources of changing wage relativities in France using a single country CGE model with foreign trade extensions.

The work presented here is part of a three-part series investigating SBTC in Australia. The first part, published as de Laine et al (2000), found evidence of SBTC in the Australian economy using industry level cross-section, time series data covering 1978 to 1998. It found evidence of SBTC to be stronger in the manufacturing sector than for the economy as a whole. The study also reports a stronger relationship between technological change and demand for skilled workers in the period following microeconomic reform (post 1985).

The second part of the series, Stone and Marshall (forthcoming), examines firm level data for similar evidence of SBTC. One important finding from this part of the study is the feedback, or endogeneity, that exists between skilled workers and technical change.[9] Once accounting for this endogeneity, evidence of SBTC is

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theory and partly a matter for conjecture/experience. For instance, shifts in consumer demand for a product that cannot be explained through income or price substitution effects are ascribed to changes in tastes. They could, however, be due to other factors such as changes in quality or data classification. CGE models cannot, generally, specifically identify these types of effects.

9 This feedback refers to the fact that the existence of highly skilled labour generally calls for the installation of state-of-the-art equipment, while at the same time, sophisticated equipment

found. The existence of endogeneity (and the implications stemming from it) casts doubt on the ability of partial equilibrium analysis to accurately capture the effects of technology on the relative employment of skilled workers. Thus, the usefulness of a GE approach becomes even more apparent.

Chapter 2 of this paper describes the method and model used. The MONASH model is used to solve for those variables which are not directly observable (such as technical change), but important in determining changes in the Australian economy between 1987 and 1994.[10] Chapter 3 discusses the results from the historical simulation and the results of the decomposition simulation that identifies the sources of change in the Australian economy. Chapter 4 looks at the specifics of changes on an industry level, including an examination of some industry-specific outcomes. Finally, chapter 5 presents general conclusions and policy implications.

generally requires skilled professionals to operate. This type of relationship may work with less skilled workers as noted in the text prior to section 1.1. The problem with endogeneity has been cited in the literature. See Chennels and Van Reenen (2000) for a discussion.

10 The MONASH model refers to a highly detailed general equilibrium model of the Australian economy developed at the Centre of Policy Studies and the Impact Project at Monash University. See Dixon and Rimmer (forthcoming) for details.

2 Background and method

Chapter 1 outlined the benefits of general equilibrium analysis in addressing some of the concerns surrounding the empirical analysis of the changing use of skilled and less skilled workers. A general equilibrium framework provides a method to deal with such problems as those arising from a single-sector focus, technology proxies and using factor content as a measure of bias. This paper will attempt to address some of the shortcomings noted in the literature on SBTC, as well as provide further direct evidence of the possible forces behind changing earnings distribution in Australia. This chapter provides an overview of the technique used in the paper to analyse the effects of technical change on the employment of skilled and less skilled workers.

2.1 Model

The MONASH model of the Australian economy is used to estimate the effects of technical change and trade on relative employment of skilled and less skilled labour. MONASH is a highly disaggregated general equilibrium model distinguishing between 113 industries and 115 commodities and therefore providing a very detailed framework with which to explore the role of technical change in the economy. A comprehensive description of the MONASH model can be found in Dixon and Rimmer (forthcoming).

2.2 Method

CGE models are most commonly used to look to the future, either in forecasting or in policy analysis.[1] However, such models are also well suited to exploring the causes of historical economic change, which is the aim of this paper. A recent example of such a CGE application for Australia can be found in Dixon, Mennon and Rimmer (2000). From a technical standpoint, the difference between forward looking policy/forecast uses of CGE models and backward looking historical uses lies in what is assumed known and what is left to the model to solve. The latter

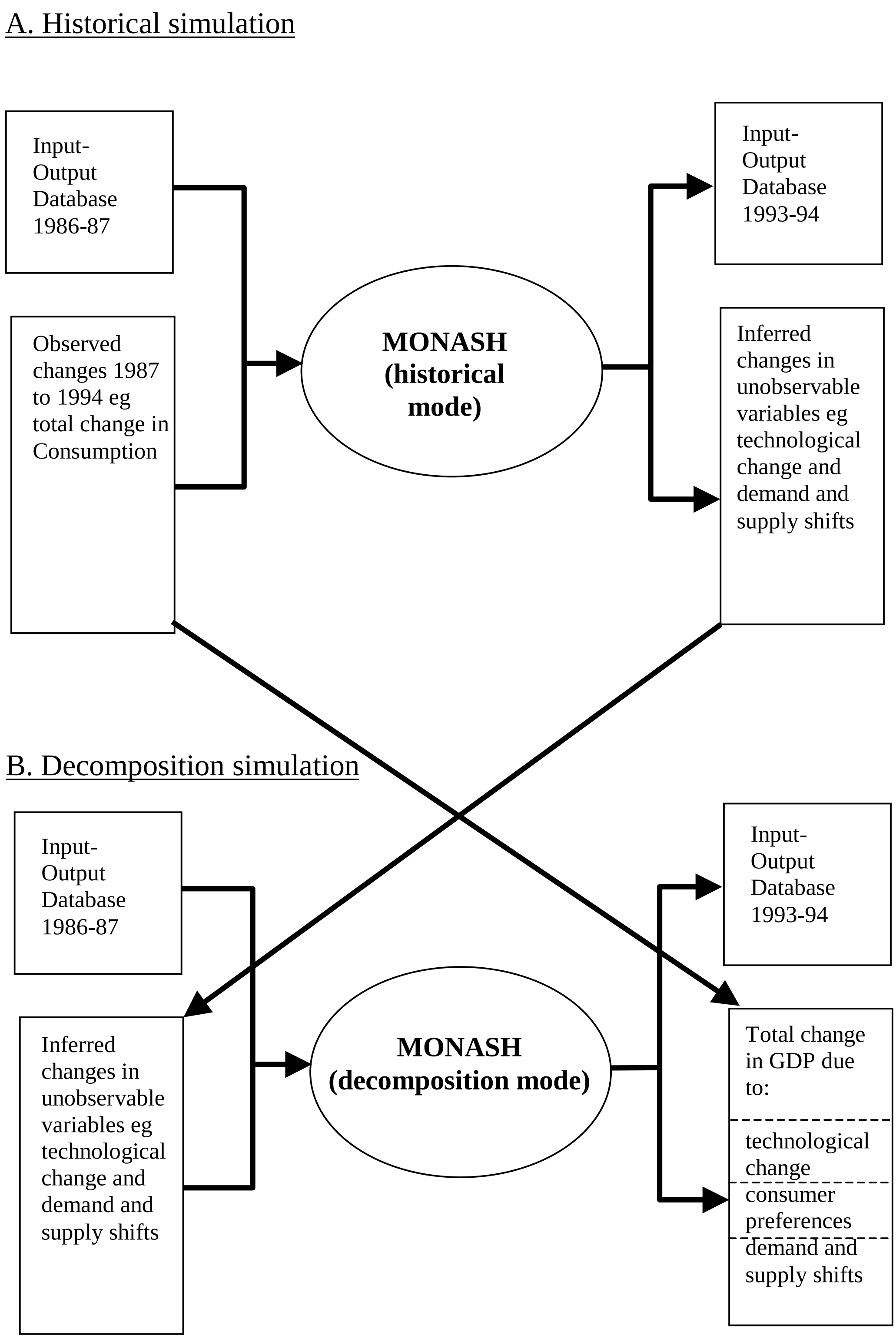
[1] For an example of the former, see Meagher (1997). For examples of the latter, see IC (1997) and PC (1999).

group of variables is determined outside the model and is termed 'exogenous'. The former group is explained within the model and is termed 'endogenous'. Prior knowledge of economic variables pertaining to an historical period can be exploited to infer the behaviour of unobservable variables over that period. This technique, known as an historical/decomposition simulation, is illustrated in figure 2.1 and discussed further in appendix A.

The top panel in figure 2.1 gives an overview of the workings of an historical simulation. Changes in unobservable variables (eg technology) are inferred from information already available about changes in the economy (eg the total change in consumption) and the assumptions made about economic behaviour (eg firms maximise profits). Thus, in the historical simulation, things that are known about history are set exogenously in the model, and things which are unobserved, or endogenous, are solved for.

In the bottom panel, illustrating the decomposition simulation, the exogenous/endogenous state of the variables is reversed. The values for the changes in certain groups of unobservable variables obtained from the historical simulation are now set exogenously in the model. The model then attributes economic outcomes of the now endogenous variables (such as total change in consumption), to these exogenous ones (such as technological change). A summary list of endogenous and exogenous variables in the two simulations can be found in appendix A.

Figure 2.1 **Partitioning history in MONASH**



Model enhancements

In standard applications of the MONASH model, employment of workers in each occupation moves in the same proportion as the change in each industry's total employment. This assumption does not allow the proportions of skilled and less skilled workers within any industry to change, as would be required to understand the increase in the relative employment of skilled workers. In this paper, the model structure is modified, assuming that:

- firms differentiate their employment of workers based on skill; and
- the way in which industries substitute between labour and capital differs according to labour skill.

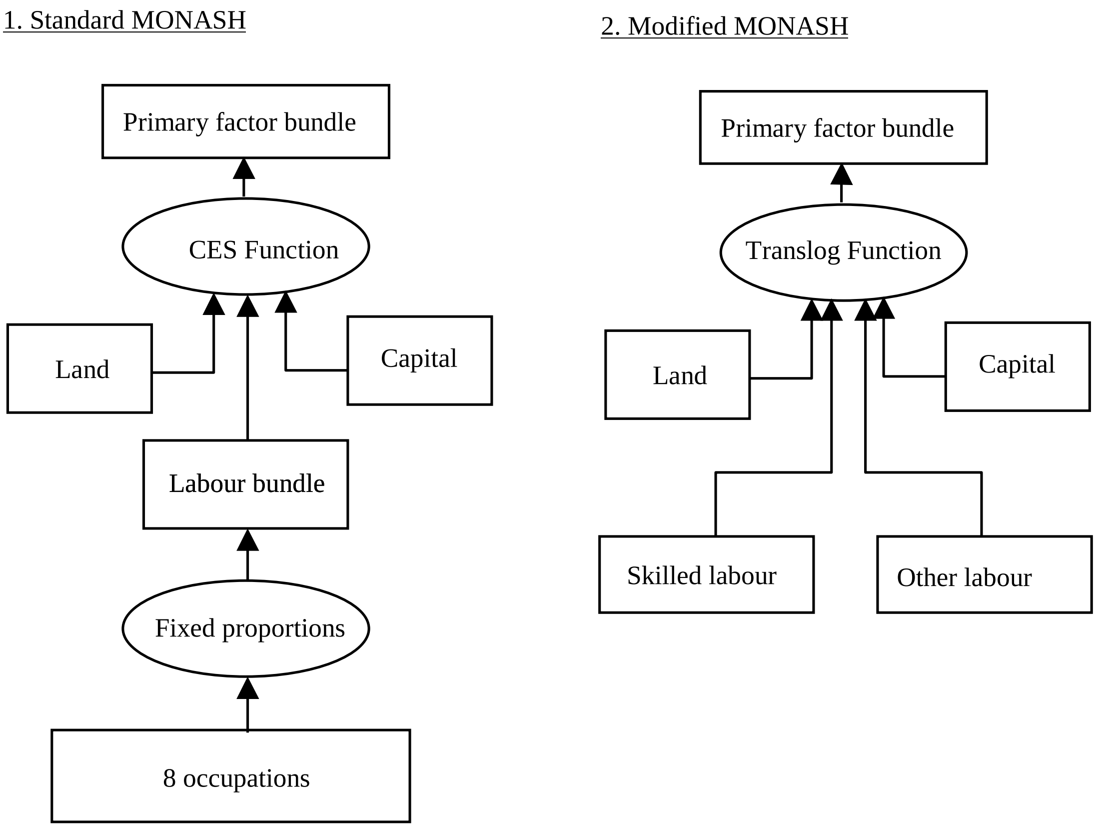
These assumptions are designed to introduce greater flexibility into modelling producers' decisions to use different types of labour. The second assumption is motivated by the growing evidence produced in overseas studies that points to the likely complementarity between capital and skilled labour in the production process (for example, Anderson and Thursby 1986, Krussell et al. 1997, and Tyers and Yang 2000).

The eight ASCO1 occupations for which detailed industry wage and employment data are available are aggregated into two categories: skilled workers and less skilled workers as defined in chapter 1. The modelling of producers' decisions in MONASH is then modified to allow for differing degrees of substitution between primary factors, ie to incorporate pairwise elasticities of substitutions between the three primary factor inputs: skilled labour, less skilled labour and capital.[2] Although land is included as a primary factor input, its use by each industry is assumed to be fixed in the simulation period. The modified production technology is illustrated in figure 2.2.

The demand for each input in MONASH is now based on a translog production function. This form is particularly well suited to the purpose of this paper in that it allows pairwise (Allen) substitution elasticities between factors to differ and these elasticities are not constrained to being positive. That is, factors can be complements as well as substitutes. A detailed treatment of the translog function in and its implementation in MONASH is given in appendix C.

[2] The authors are grateful to Professor Dixon and Dr Rimmer, of the Centre of Policy Studies at Monash University, for implementing the necessary modifications to the MONASH code and providing the appropriate suite of model files.

Figure 2.2 **Production technology in standard and modified MONASH**



There is a large body of literature which attempts to measure the elasticity of substitution between inputs for differing production (functional) forms. Early work by Berndt and Christensen (1973) looked at substitution between two types of capital and a single labour input using a translog framework. They found consistent values for a 40 year period (1929–1968) with the two types of capital being highly substitutable (with values between 4.4 and 8.4) and both being substitutable with the single labour input. Anderson and Thursby (1986), also using a translog model, looked at confidence intervals around estimations (both their own and for previous work) of factor demand and substitution elasticities. They found evidence of complementarity between white collar workers and capital. Finally, Hamermesh (1993) provides a summary of studies varying by choice of functional form, estimation technique and data used. Many of the studies provide evidence of capital–skill complementarity in the sense that the elasticity of substitution estimated between unskilled labour and capital is greater than that between skilled labour and capital.

As no prior estimates of translog pairwise elasticities of substitution are available for Australia, a review of the literature, as well as preliminary estimation using a dataset constructed for this project, was conducted. Based on this investigation, the following pairwise elasticities of substitution are applied in the translog model as implemented in MONASH:

Capital/skilled labour	0.77
Capital/less skilled labour	1.50
Skilled/less skilled labour	1.80

These values reflect what the empirical evidence has found — capital is a relative complement to skilled labour versus less skilled labour. These elasticity values are applied uniformly across all industries.[3]

Labour market settings

Modifications to the modelling of firm production technology mean that the use of labour inputs by producers differs in this application from standard MONASH applications. It is desirable, therefore, to make explicit some of the assumptions underlying the operation of the labour market in modified MONASH, in both historical and decomposition mode.[4]

In historical mode, total employment by industry is given in both periods (1987 and 1994). This means that aggregate employment is pre-determined. Occupational wages are allowed to vary, although their value is effectively constrained by the knowledge of total employment and hourly wage bills (both at the industry and economywide levels). In this paper, sector-level employment and wage bills are known for each of the two skill groups, and are used to calculate movements in relative employment and relative wages between 1987 and 1994 (see appendix B). These relative changes are then imposed on the model in historical mode.[5]

The imposition of changes in relative employment is akin to telling the model how to reallocate labour from one skill group to the other between 1987 and 1994, within the constraints of total change in industry employment. Similarly, the introduction

[3] Reliable estimates of industry-level elasticities are not available. Sensitivity analysis conducted indicates that the general results are not significantly affected by the size of the elasticities applied.

[4] For a description of the labour market in standard applications of MONASH, see Dixon and Rimmer (forthcoming).

[5] It is assumed that all individual industries belonging to a given sector experience the same proportional change in their employment and wage relativities.

of changes in wage relativities is equivalent to telling the model how to allocate the total cost of labour between skilled and less skilled workers.

Since the model is given the end-points, ie the relative employment of each type of labour as well as relative wages, it is left to determine how the economy got there. That is, it determines the degree to which the observed changes are the result of unobservable factors such as technological change. In the modified version of MONASH, a technological change biased in favour of skilled workers is represented by a 'skilled/less-skilled technical change' variable (see appendix A). A value for the technical change is then determined that is consistent with the model's theory and data given.

In historical mode, trade factors such as export and import volumes and prices, as well as taxes and tariff rates, are set exogenously in the model. What is then left to be determined are shifts in foreign demand curves and import demand functions. In the decomposition simulation changes in world prices through shifts in export demand, for example, are then set exogenously to measure their effect on changes in relative labour employment.

In the decomposition simulation, aggregate employment remains exogenous, but industry (total) employment is now endogenous, as is employment by skill group. In this simulation, the value of the skilled/less-skilled technical change variable estimated in the historical simulation becomes exogenous. As in the historical simulation, the labour market is constrained by a given change in aggregate employment, and in relative wages. From this set of constraints, the model in decomposition mode 'determines' the industry allocation of labour (including by skill group), and all labour costs (economywide, by industry, by skill group). Thus, it becomes possible to measure the effect of SBTC on relative employment of skilled and less skilled workers. This effect, by itself, can be much stronger than the shift in relative employment that was observed historically. However, when all factors are taken into account, including other unobservables and relative wage changes, the simulated change and observed change must be equal.

3 Decomposing the effects of technology

This chapter presents the macroeconomic results of the historical and decomposition simulations based on the MONASH model. Chapter 4 discusses specific industry outcomes.

To summarise chapter 2, and in more detail in appendix C, the MONASH model is modified to assume that the ease of substitutability differs between pairs of primary factor inputs. Here, the model assumes that less skilled labour is more easily substituted for capital than skilled labour. The historical simulation is conducted to provide estimates of unobservable variables, given what is known about changes in the economy between 1987 and 1994. The variables of most interest for this work are the various measures of technical change and those relating to the changing international trade environment for Australia.

Section 3.1 discusses the outcomes of the historical simulation with respect to technical change (see box 3.1) and trade variables over the period under review (1987 through 1994). A discussion of the decomposition of the trends specifically affecting the employment of skilled workers relative to less skilled workers is presented in section 3.2.

3.1 Outcomes of the historical simulation

As described in box 3.1, MONASH provides several measures of technical change. Of most interest to this work is the *skilled/less-skilled technical change* variable. This variable attempts to capture the degree to which technical change has influenced an industry's decision to use the two types of labour — skilled and less skilled — at given wages. Figure 3.1 outlines the results of the historical simulation for the *skilled/less-skilled technical change* variable at the given relative labour use (ie the ratio of less skilled to skilled labour) for all 113 industries the MONASH model covers.

The horizontal axis in figure 3.1 shows the ratio of less skilled labour to skilled labour hours. A value of one indicates the two are used in the same proportion. The

Box 3.1 Technical change in MONASH

Partial equilibrium studies often use proxies to measure technological change and these proxies can be problematic (see Chennels and Van Reenen 2000 for examples of pitfalls in using technology proxies). A general equilibrium approach, using a fully specified set of equations, can estimate technological change through the use of shift variables. They work, in a broad sense, as follows.

MONASH contains the following generalised production function:

$Z_h = F(X_{1h}/A_{1h}, X_{2h}/A_{2h},\ldots,X_{ih}/A_{ih})$

Where:

- Z_h = output in industry *h*;
- X_{ih} = use of input *i* (where *i* = 1 to 113 intermediate inputs, skilled labour, less skilled labour, capital and land) by industry *h*;
- A_{ih} = variable allowing input *i* saving technical change in industry *h*.

In an historical simulation, Z_h and X_{ih} are known, leaving the model to solve for A_{ih}. As implemented, A_{ih} is segmented into various components: technical change affecting the use of all inputs (here termed *other technical change)*; technical change affecting the relative use of all types of labour with respect to capital (*labour/capital technical change)*; and technical change affecting the relative use of skilled labour with respect to less skilled labour (*skilled/less-skilled technical change)*. *Other technical change* includes a measure of change in the use of all primary factors of production, in other words, a measure of multifactor productivity.

The technical change variables dealing with specific inputs, *labour/capital technical change* and *skilled/less-skilled technical change*, both represent cost-neutral changes in an industry's technology affecting producers' choices of the primary inputs of capital and labour. Cost-neutral means these are changes in the choice of inputs unrelated to changes in relative prices of the inputs. Assuming no changes in industry *h's* output and input prices, then the change in that industry's relative demand for labour and capital can be stated as:

Percentage change in labour demand(*h*) - percentage change in capital demand(*h*) = Labour/capital technical change(*h*)

For example, if industry *h's* demand for labour falls 50 per cent, while the demand for capital increases 60 per cent, at given prices for capital and labour, the value for *labour/capital technical change* would be -110 per cent (-50% - 60% = -110%) while the percentage change in the labour/capital ratio would be -70 per cent.

(Continued next page)

Box 3.1 (continued)

An example is as follows:

	Labour (units)	Capital(units)	Labour/capital(ratio)
Initial period	10	5	2.0
Next period	5	8	0.6
Percentage change	-50%	+60%	-70%

A negative value for *labour/capital technical change* indicates a technical change that favours the use of capital.

Skilled/less-skilled technical change works analogously. It is the cost neutral change in an industry's technology affecting producers' choices of the inputs of skilled labour and less skilled labour. A positive value indicates a technical change favouring the use of skilled labour.

A note of caution should be made with respect to these technical change variables. By their very nature, ie being unobservable and calculated as a residual, any value attached will also capture non-technology-related influences not explicitly modelled. Examples of these are changes in preferences induced by changes in the tax law, changes in product quality, changes in ABS classifications, as well as more general factors such as weather, not specifically controlled for. However, given that these implicit factors are often specific to certain industries and/or points in time, the consistency of the technology findings across industries indicates they are most likely a reflection of genuine technical change.

Sources: Dixon and Rimmer (forthcoming) and PC estimates.

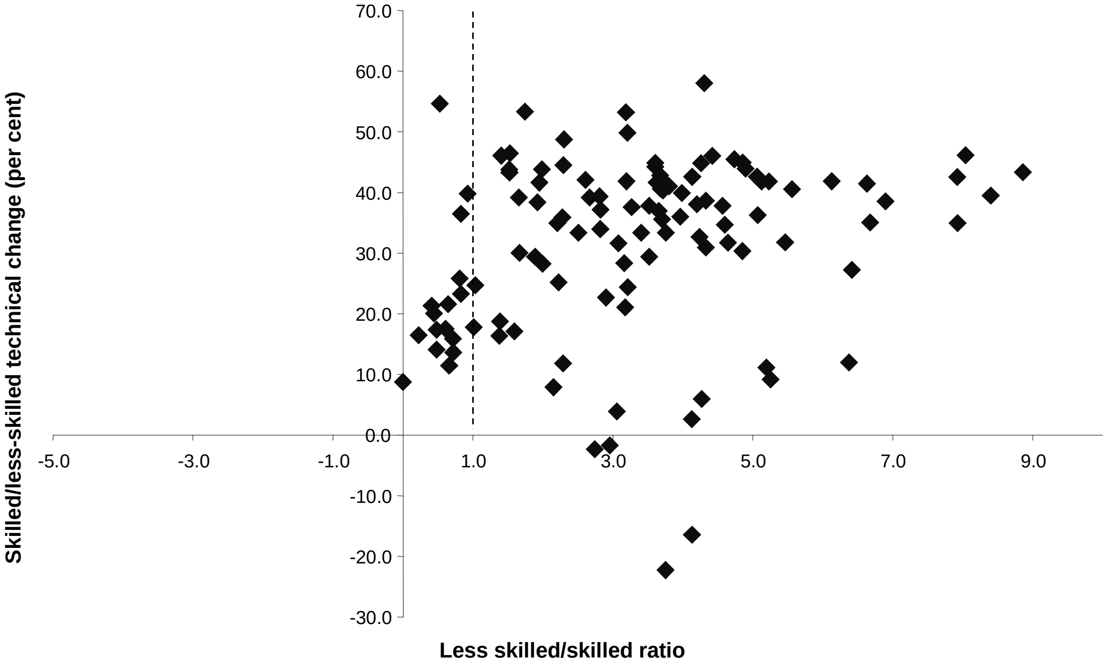
vertical axis shows the measure of technical change specific to the two labour inputs. It is the contribution of technical change to the total percentage change in the relative use of the two types of labour at given wages.

Most industries have positive values for *skilled/less-skilled technical change,* as shown in figure 3.1. Non-zero values imply that changes in the wages of skilled and less skilled workers, changes in the prices of other inputs, and changes in outputs do not fully explain the observed changes in the mix of labour employed. Positive values indicate that technical change has been biased in favour of the use of skilled workers and thus provide initial support for the SBTC hypothesis.

The graph shows that most industries in Australia use relatively more less skilled labour than skilled labour, ie most of the observations are to the right of the dashed line. Also shown, most of the values for *skilled/less-skilled technical change* are between 25 and 45 per cent. Two outcomes can be inferred from this.

Figure 3.1 **Technical change effect *versus* relative labour use** [a]

1987–1994



[a] Values for ratio taken for hours worked in 1994. The dashed line indicates equal proportions of the two types of labour. The four industries experiencing a negative *skilled/less-skilled technical change* are iron-ore, oil & gas, gas, and nonbank financial services.

Data source: PC estimates using the modified version of the MONASH model.

First, the increase in the relative use of skilled workers economywide is not just a result of an expansion in skill-intensive industries. The graph shows that positive values for the *skilled/less-skilled technical change* variable are found regardless of the relative labour use (ie skilled or less skilled intensive) of the industry. Second, the positive value for the *skilled/less-skilled technical change* variable is pervasive, positively affecting the employment of skilled labour across the economy. That is, it is not confined to traded, or trade-competing industries.

As described in box 3.1, technology factors are taken to be the most important elements which are not explicitly given to the model. These factors are independent of changes in costs to the firm, that is, the prices of factor inputs. There are several technology measures that enter into the demand for each input. These include general economywide factors, changes that affect the demand for all primary factors, as well as changes in production methods which influence a firm's relative use of total labour, capital and intermediate inputs. The variable *skilled/less-skilled technical change* captures changes in technology separate from these other measures. It applies exclusively to the demand for skilled and less skilled labour.

While this measure will pick up other non-technology related changes, some of these other changes will be lost at the aggregation level applied here (ie the level of labour aggregation) or are not consistent or pervasive across the economy.[1] Some of the variation in the size of the technological change across industries may be due to these other factors, but not its existence.

Figure 3.2 shows the outcomes for *labour/capital* and *multifactor technical change* arrived at in the historical simulation for 24 sectors of the Australian economy.[2] The *labour/capital technical change* variable measures the degree to which changes in technology affect an industry's choice between capital inputs and labour as a whole. A negative value favours capital. The *multifactor technical change* measures the extent to which all inputs can be reduced when producing the same level of output. A positive value indicates input-saving technology. *Multifactor technical change* added positively to output for all sectors, with the exception of the retail sector which shows virtually no effect.[3] This is consistent with evidence presented elsewhere of increased multifactor productivity (MFP) in Australia (Parham and Kennett forthcoming). Thus, over and above technical change affecting relative labour and capital usage, there is evidence of technical change that led to a general reduction in inputs needed to produce a given level of output in the economy. That is, a general improvement in productivity.

Most of the sectors shown in figure 3.2 returned a negative value for *labour/capital technical change*. This implies that overall, the Australian economy experienced technical change biased toward the use of capital over labour at constant factor prices. Looking at figure 3.3, most sectors experienced an increase in capital use between 1987 and 1994 relative to employment growth. Indeed, there has been an increase in Australia's capital–labour ratio in this time frame (Parham and Kennett forthcoming). Overall, in the period 1987 to 1994, the Australian economy seems to have achieved higher levels of productivity while increasing its use of capital and labour — not by substituting capital for labour to the extent that labour inputs declined.

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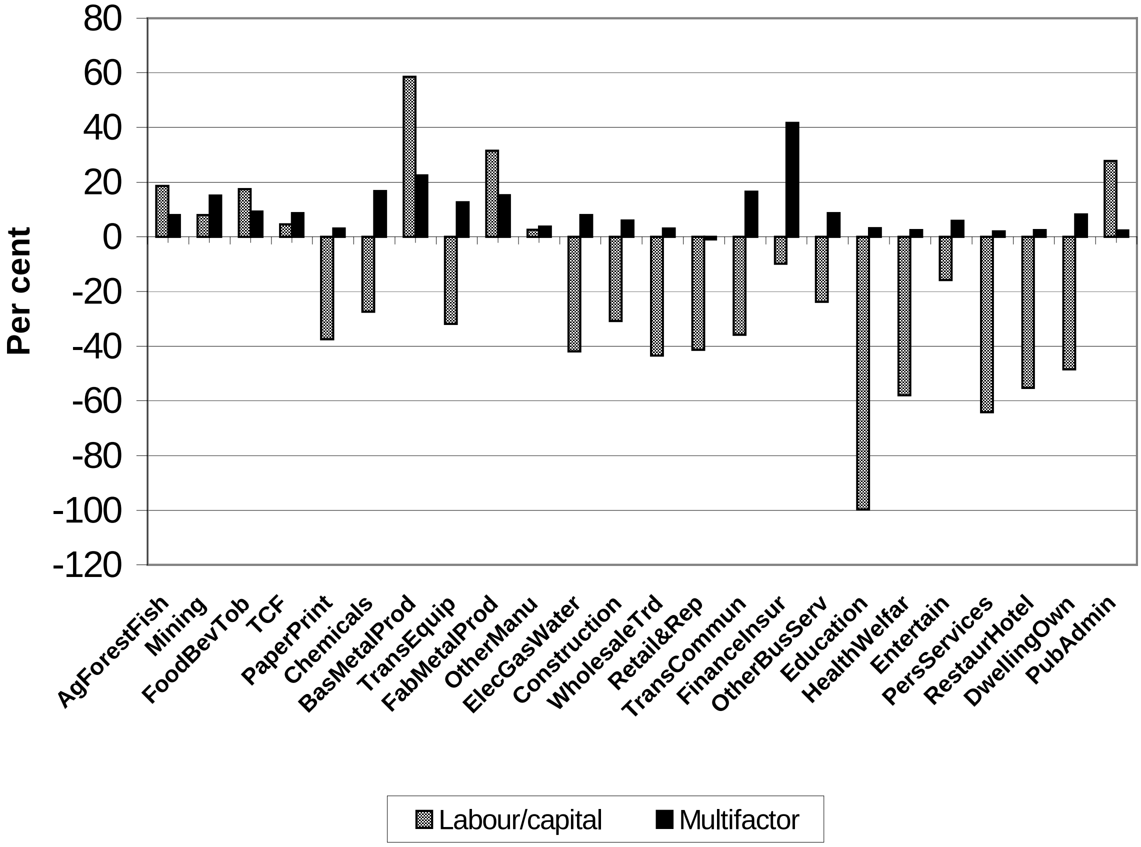
1 For example, reforms started in 1989 which led to the greater corporatisation and contracting out of government activities may have had an effect on the relative use of skilled versus less skilled labour in these organisations. Short-term contracting in response to a time-specific events is another example. However, these affect specific industries and/or time periods. The pervasive nature of the results presented here indicates forces beyond these events.

2 For ease of presentation, 24 sectors are shown rather than all 113 industries. The overall pattern of the results is the same.

3 As stated in chapter 1, this industry experienced most if its employment growth in the form of part-time workers. This may influence the productivity measures used here. See PC (1999) for a discussion of changing productivity levels and the effects on specific industries.

Figure 3.2 **Multifactor and labour/capital technical change**[a, b]
1987 and 1994



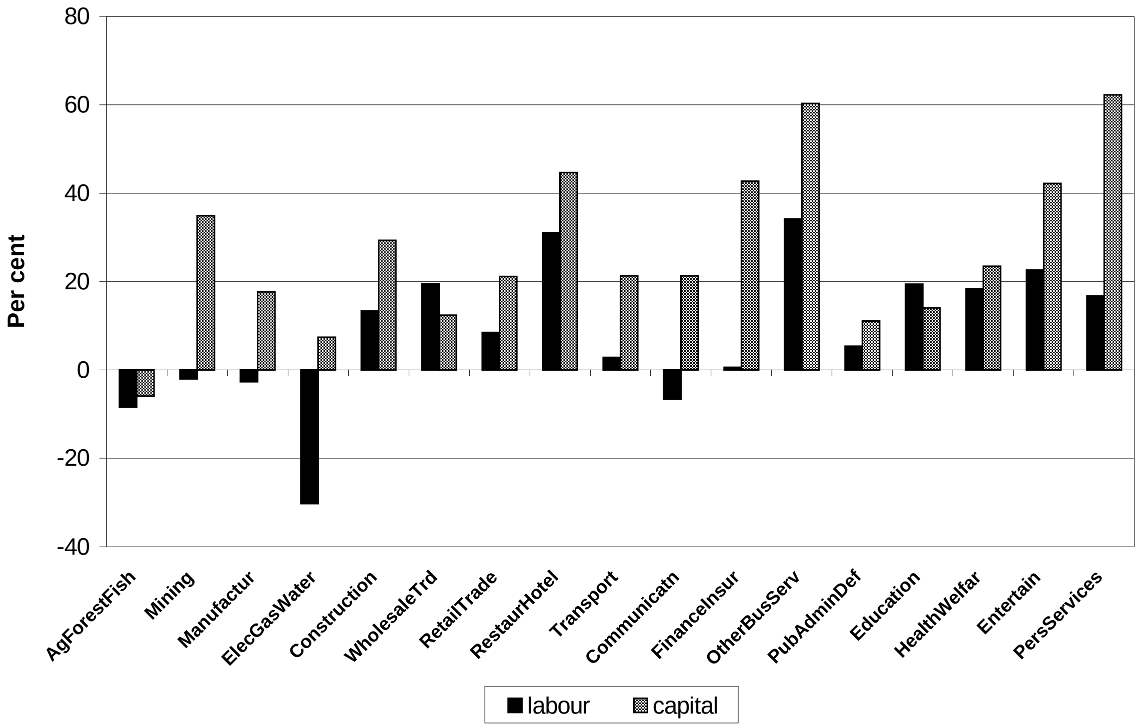
[a] A negative value in the labour/capital measure indicates a shift in favour of the use of capital. See box 3.1 for an interpretation of these values. [b] The large shift observed in the education sector (-99 per cent) comes from a relatively large increase in the use of capital (almost 30 per cent between 1987 and 1994) on a very small base (roughly 5 per cent of the total of capital and labour inputs).

Data source: PC estimates based on the modified MONASH model.

It would appear that, overall, the Australian economy became more capital intensive in the period under review. Much of this ‘capital-deepening’, as it is sometimes referred to, took place in response to factors other than relative price changes. The *labour/capital technical change* variable shows that for most sectors, technical change biased toward the use of capital played a significant role.

While the economy was becoming more capital intensive between 1987 and 1994, it was also increasing its relative use of skilled labour. The results of the simulation suggest that, as with capital, technological change contributed to this shift. SBTC predicts that technological effects will be biased in the use of skilled workers. With a few exceptions, positive measures of technical change have been found economywide, that is, biased toward the use of skilled labour.

Figure 3.3 **Growth of capital and labour inputs by sector**
Between 1987 and 1994



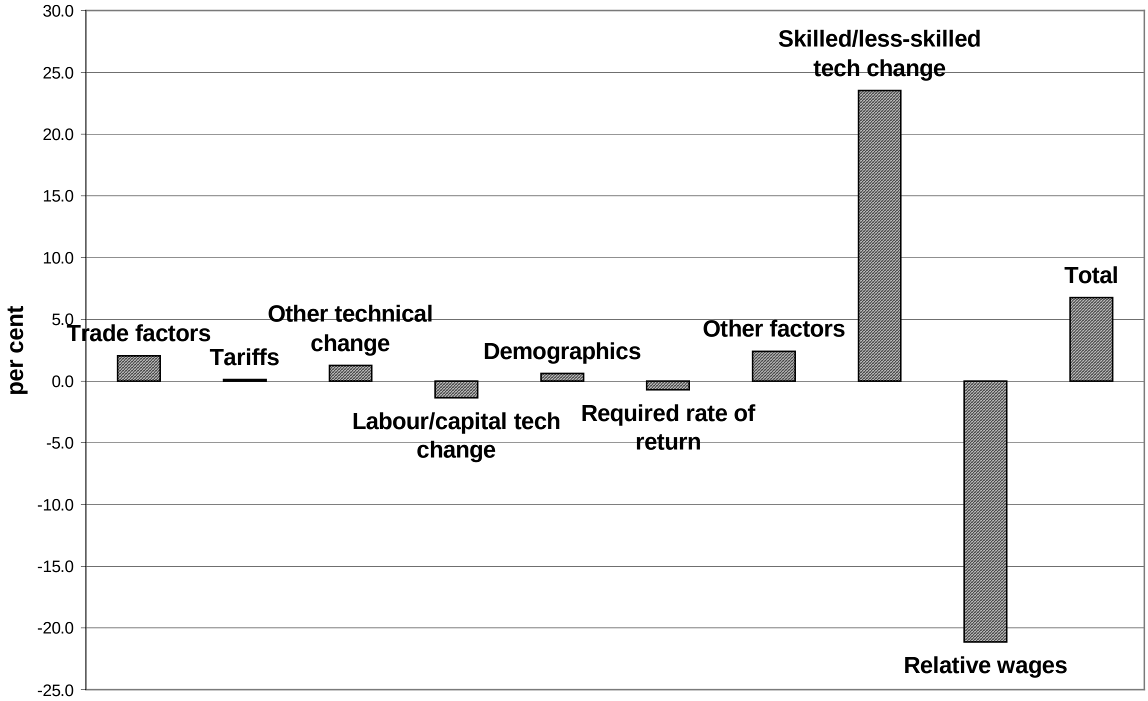
Data source: PC estimates based on the modified MONASH model.

3.2 Change in the relative employment of skilled labour; outcomes of the decomposition simulation

This section analyses the results of the decomposition simulation. It highlights the individual contributions of selected exogenous variables to the economywide change in the relative employment of skilled labour. The variables shown are chosen based on the extent of their contribution to the observed increase. Figure 3.4 presents the results of the decomposition simulation.

Figure 3.4 **Decomposition of change in relative employment [a]**

Per cent change between 1987 and 1994 due to specified causes



[a] Relative employment refers to the change in the relative employment of skilled labour versus less skilled labour. Each bar represents the contribution (in per cent) of the variable to the total change.

Data source: PC estimates using the modified version of the MONASH model.

The two factors driving the observed change in the relative employment of skilled workers are technological change favouring the employment of skilled workers (*skilled/less-skilled tech change*) and the increase in the relative wages of skilled workers (*relative wages*). Technical change, holding all other factors constant, would have led to an increase in the relative use of skilled workers of 24 per cent. However, the increase in the relative wage of skilled workers, other factors held constant, would have reduced relative employment of these workers by 21 per cent. Thus the net result of the two factors is a positive change of 3 per cent (that is, a shift toward the use of skilled labour). The increase in the relative wage can be seen as a response to the other factors that caused increased demand for skilled workers.

Changes in Australia's export demands and import prices (*trade factors*) have positively influenced the relative employment of skilled workers. Exports have been the major contributing factor to this outcome, increasing relative employment of skilled workers by almost 3 per cent. Exports are the driving force behind Australia's terms of trade improvement in this period, expanding output in the economy and thus demand for labour. These *trade effects* in total, contributed about 2 percentage points to the overall growth in the relative use of skilled workers.

Tariffs changes have had virtually no effect on the increase in the relative employment of skilled workers economywide. Thus, reducing protection does not appear to have much direct influence on relative employment, nor does it appear to have unduly harmed less skilled workers as implied by the trade hypothesis. Of course, changes in tariffs could have indirect effects; for example, encouraging the use of new technologies.

Together these results seem to indicate that changes in Australia's trade position have had little effect on the change in the relative employment for skilled workers.

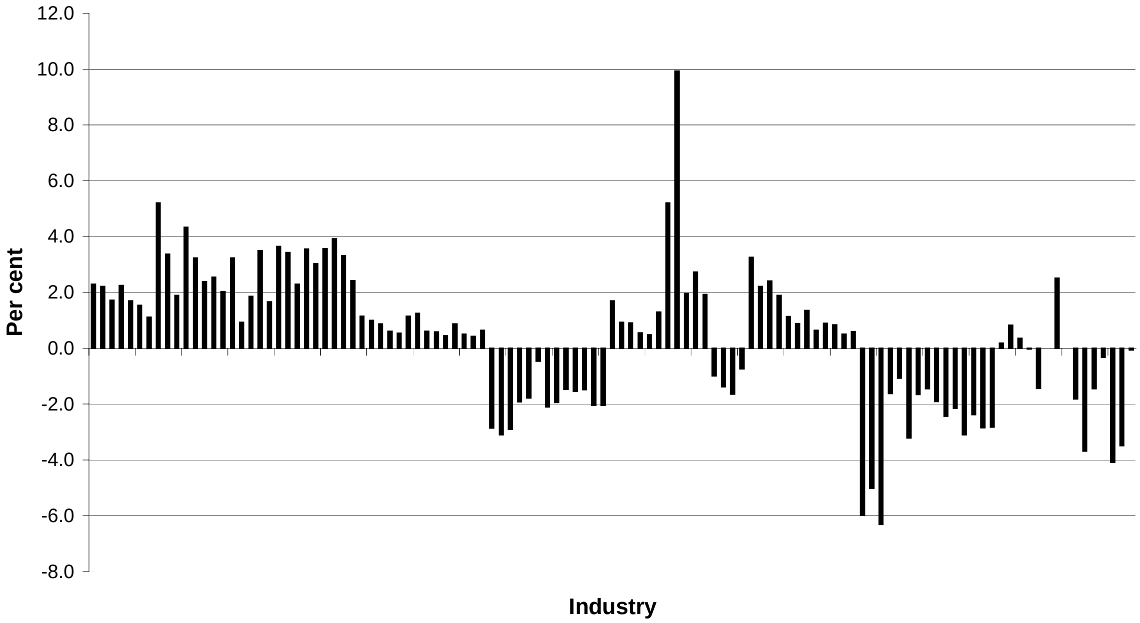
Multifactor productivity changes affecting the economy, captured in the *other technical change* variable, slightly favour the employment of skilled workers. The *labour/capital technical change* variable, on the other hand, contributed negatively to the relative employment of skilled workers. As shown in figure 3.2, a change in technology favouring the use of capital occurred in most sectors in Australia between 1987 and 1994. Given the assumptions made (that capital and skilled labour are less substitutable than capital and less skilled labour), this growth in capital inputs should have been beneficial for skilled labour — yet it is not. Indeed, this technical shift produces the largest negative impact on relative employment of skilled workers after *relative wages*.

Figure 3.5 shows the contribution of *labour/capital technical change* to the change in the relative employment of skilled labour for each of the 113 industries modelled.[4] As shown, in more than half of the industries this technical change contributed to an increase in relative skilled employment. This is expected given the underlying assumptions of the model. However, the size of the shift against skilled employment in a few of the industries, namely, in the electricity, gas and water industries (I84-I86), was such that the economywide change appeared to go against skilled workers. In these three industries, the *labour/capital technical change* led to a reduction in both types of labour (see figure 3.3). However, less skilled workers suffered to a lesser extent than skilled workers, thus leading to an increase in their relative employment.

[4] See appendix B for a listing of these industries.

Figure 3.5 **Change in relative skilled labour employment attributable to labour/capital technical change by industry[a]**

Between 1987 and 1994



a Horizontal axis shows MONASH industries from 1 to 113. See appendix B for a listing of these industries.

Data source: PC estimates based on the modified version of the MONASH model.

The measure of capital used may also play a role in explaining the negative contribution of *labour/capital technical change* to the relative employment of skilled labour observed in some of the industries in figure 3.5. As stated in section 2.2, evidence of capital–skill complementarity has been found in industrialised economies. This is particularly evident when capital is broken into its relevant components. That is, when separate measures for equipment, buildings, and even computers, are used, some measures of capital and skilled labour are shown to be complements (see for example, Krussell et al. 1997 and Anderson and Thursby 1986). To the extent that the rise in the capital–labour ratio is driven by increases in non-complementary components such as building and structures, an increase in the relative use of skilled labour would not necessarily be expected.

For example, the shift away from skilled employment coming from the *labour/capital technical change* in the most of the transport services industries (I93-I97) is a result of a decline in skilled, and an expansion in less skilled, employment. The type of capital associated with these industries is most likely bias in the use of less skilled labour intensive (such as an expansion in call centres). Just as breaking down labour into its relative components provides additional insight into factors driving overall employment trends, segmenting capital may further explain why the technological shift resulting in its increase, has reduced relative employment for skilled labour overall.

Demographics is the aggregation of measures affecting such factors as growth in the number of households and labour force size. As shown in figure 3.4, these changes have led to a slightly increased use of skilled workers relative to less skilled workers. As the types of ‘common’ household products used (such as computers or automated temperature control units) require increasingly sophisticated techniques to produce and maintain, this trend is likely to continue.

As described in chapter 2, during the historical simulation, values of such economic variables as investment and capital stock are set exogenously. Thus, unobservable variables, such as apparent changes in the required rate of return on investment, are determined in the simulation. During the decomposition simulation, this apparent change in the required rate of return is set exogenously and its effect on other economic variables, such as relative skilled labour employment is measured.

The results of the decomposition simulations indicate that an increase in the *required rate of return* contributed to a decline in investment and capital stocks in the economy, all else equal. This contributed to a decline in the relative use of skilled labour. As explained above, the model assumes capital and skilled labour are not as easily substitutable as capital and less skilled labour. Change in the *required rate of return* produces the expected result given these assumptions. That is, in general, factors negatively affecting the use of capital will decrease the demand for skilled workers with respect to less skilled workers.

Other factors include what is known about investment–capital ratios, the average propensity to consume, government demand factors, etc. Taken as a whole, these factors have a small but positive influence on the change in the relative employment of skilled workers.

Overall, figure 3.4 shows that, given changes in technology, trade factors, capital use, demographics, and other factors, the relative employment of skilled workers would have risen 28 per cent between 1987 and 1994. However, relative wage increases reduced relative demand by 21 per cent, leading to an overall increase in relative employment of 7 per cent. Trade appears to have played a relatively minor role.

Findings by both Jean and Bontout (2000) and Tyers and Yang (2000) are consistent with the results presented here. Jean and Bontout found that technical change and factor supplies (as here, supplies exogenously given to the model) are by far the most important contributors to the total change in the relative employment of skilled workers in France between 1972 and 1992. Tyers and Yang also found that technical change biased in favour of skilled workers explains the observed increase in the skill wage premiums for the countries they studied.[5] They conducted their simulations contrasting two assumptions about capital–labour complementarity. Under the assumption of capital–skill substitution they found their results stemmed from skill enhancement. That is, the observed increase in skill wage premiums is due to the enhancement of individual skills possessed by workers. Under the capital–skill complementarity scenario, they found that the increase in the wage premiums resulted from capital enhancement. That is that the demand for skill arises from the need for skilled workers to operate new capital equipment. Tyers and Yang argue that the latter explanation conforms to broader trends and observations.

The results presented here show that capital enhancement, both in quantity and due to technical change, has taken place in the Australian economy. As shown in figure 3.5, for most industries the movement toward capital has acted to increase relative employment of skilled workers. This increase is in line with the capital embodiment argument put forth as part of the SBTC hypothesis. It states that the capital deepening (and the technology 'embedded' therein) which has taken place across most industrialised economies over the past decades has led to the increased demand for skilled workers. The relationship between capital and skill shown in this analysis provides some support for this contention.

Finally, the positive influence on the change in relative employment of the broader measure of technical change (*other technical change*) provides further support for SBTC.

Overall, the results provide more support for the SBTC hypothesis than for the trade hypothesis. The outcomes also highlight the positive role capital has played in this process. While technical changes have acted to increase the employment of skilled workers, relative wages reduce the total effect. Again, the role of trade in explaining these outcomes appears to be small.

In the following chapter, a more detailed analysis of the demand for skilled and less skilled labour are presented in the context of a discussion of changes in such demand by selected industries.

[5] The focus is on older industrial regions; the US, the European Union and an amalgam of Canada, Australia and New Zealand.

4 Industry outcomes

The main objective of this paper is to identify the forces behind the observed increase in the employment share of skilled labour in the Australian economy. That is, the growth in skilled employment relative to less skilled employment. The previous chapter presents evidence that most Australian industries, between 1987 and 1994, experienced technical change that biased them toward the use of skilled workers. This finding provides broad support for the SBTC hypothesis over the trade hypothesis. The evidence comes primarily from the large positive contribution of the s*killed/less-skilled technical change* variable to the overall change in relative skilled labour employment and an increase in the relative wages of skilled workers. Trade variables contribute only slightly to the observed change.

While the individual industry results are broadly consistent with those found at the economywide level, the underlying forces driving specific industry outcomes differ. This chapter reports the results for three selected industries in order to highlight these differing forces. The three industries are textiles (I34), other business services (I103), and wholesale/retail trade (I89/90).

The textiles industry is examined because it is often considered to be the quintessential industry in arguments in support of the trade hypothesis over SBTC. An examination of this industry proves insightful in contrasting the two hypotheses.

The service sector provides most of the employment in Australia and is the primary source of job growth as well (Adams and Meagher 2000). Other business services is chosen as an example of this growth in the period under review for this sector (see figure 3.3).

Finally, the wholesale/retail trade industry has also seen strong employment growth over the past decade and is forecast to be one of the highest performing sectors in the Australian economy (Adams and Meagher 2000). An examination of trends that drive employment growth in this industry may prove insightful for other industries.

4.1 Industry outcomes[1]

The manufacturing sector as a whole experienced a decline in employment between 1987 and 1994 of 2.7 per cent (see figure 3.3). However, the rate at which the sector shed skilled workers is smaller than that for less skilled workers, thus relative employment of skilled increased by just over 7 per cent.

The individual industry results vary widely across the manufacturing sector, which covers over 60 of the specific industries modelled in MONASH. As stated earlier, the textile industry warrants detailed discussion because it is often used as an example of how increased imports from low-wage countries have led to a reduction in the share of less skilled workers in total employment in industrialised economies, including Australia.

Textiles

According to the Industry Commission report into the textile, clothing and footwear (TCF) industries (IC 1997), a major contraction took place during the 1989 to 1992 period, when production fell in this sector due to a number of factors. These include the domestic recession and increased import competition. Over this period, TCF lost 18 per cent of its workforce (IC 1997). The textile industry itself, has undergone rapid change in the past 20 years. For the 1987–1994 period, both output (-6 per cent) and total employment (-21 per cent) have fallen. At the same time, total capital stock increased (over 10 per cent), especially machinery and equipment stocks (over 18 per cent) (IC 1997). However, the employment of skilled workers has declined at a slower rate (16 per cent) than that of less skilled workers (23 per cent). The discussion below focuses solely on the textile industry.

The decomposition simulation results for the textile industry are presented in figure 4.1. This figure, which is similar to the one presented in chapter 3, shows the contribution of each factor to the change in employment of the two types of labour. As stated above, the total employment of skilled workers relative to less skilled workers increased by just over 7 per cent.[2]

The first two columns, labelled *exports*, show the contribution of changing export demand to the employment of each type of labour. Textile exports increased over the period under review, yet this increase was achieved with fewer units of labour. Employment of less skilled workers fell by slightly more than the employment of

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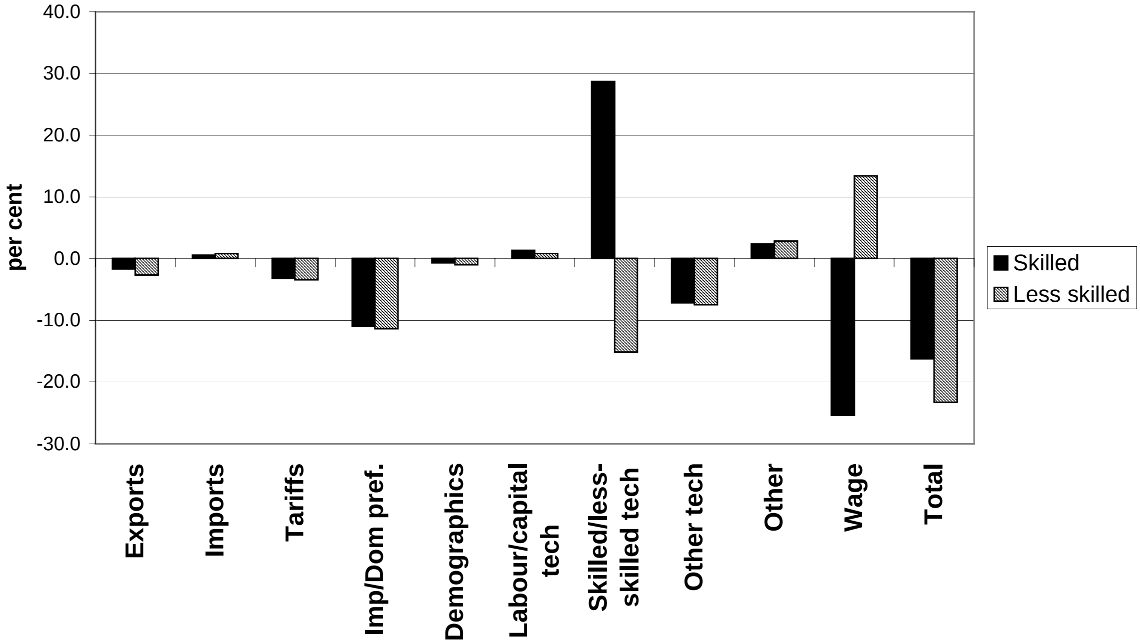
[1] Appendix D contains the details for the outcomes by industry.

[2] As noted in chapter 2, changes in an individual industry's relative employment are constrained to conform to known sector level changes.

skilled workers, leading to a relative rise in skilled worker employment due to changing export demand.

Figure 4.1 **Factors contributing to the change in employment, Textiles[a]**
1987–1994



[a] Simulation results decomposing the contribution of each factor to the percentage change in employment for each type of labour.

Data source: PC estimates using a modified version of the MONASH model.

The next factor measures the contribution of the change in *imports*. According to the trade hypothesis, it is the decrease in import prices and/or the increase in imports which leads to a displacement of domestic production and decreases the demand (and wages of) less skilled workers. Import prices increased in this industry between 1987 and 1994, but less than the domestic prices for textiles. As the figure 4.1 shows, this change in import prices (given domestic price changes) contributed to a small but positive increase in employment of both types of workers. Indeed, the growth in less skilled workers is actually larger than the growth in skilled workers (although the contribution to both types of workers is quite small). This is inconsistent with the trade hypothesis, according to which rising imports lead to declines in less skilled worker employment and relative wages.

Changes in *tariffs* over the time frame have reduced employment of both types of workers in the textile industry.[3] This result is consistent with an implication of the trade hypothesis that a reduction in tariffs leads to increased imports which can then lead to a reduction in domestic production and thus, employment, in the affected industry. However, the tariff changes appear to have had similar impacts on both types of labour, rather than having a larger impact on less skilled labour as the trade hypothesis implies.

The next variable, *imp/dom pref* refers to the import/domestic preference shifter. This variable measures the extent to which producers and consumers have shifted their demand for imports, all else equal.[4] While the import/domestic preference shifter accounts for over 10 percentage points of the decline in employment, the consistency of the effect across both types of labour indicates that it has little ability to explain the relative increase in skilled employment. Thus, it does not support either of the two hypotheses, per se.

Both *demographic* factors and *labour/capital tech* (labour/capital technical change) contribute very little to changes in the employment of either type of labour for the textile industry.[5]

The next factor is the skilled/less-skilled technical change variable (*skilled/less-skilled tech*). It has the largest effect on skilled labour of any of the variables. It has contributed to a rise in the employment of skilled workers of close to 30 per cent. This technical change acted against less skilled labour, contributing to a decline in employment of almost 15 per cent. Thus, between the two, almost 45 per cent of the increase in the relative demand for skilled workers is attributable to this factor.

Other tech (other technical change) served to reduce employment of both types of labour. Yet the reduction suffered by less skilled workers is slightly more than that experienced by skilled workers. This factor then contributes positively to the change in relative skilled worker employment. All three technology measures examined contribute positively to the increase in the relative employment of skilled workers.

[3] While the size of the tariff effect is small (less than 5 per cent) for textiles, other industries under the broad Textile, Clothing and Footwear heading exhibited larger employment changes due to tariff effects. In the footwear industry, almost half of the decline in skilled worker employment is due to tariff changes. However, these changes led to a similar decline for less skilled workers in footwear, providing no insight into relative employment changes.

[4] This preference shifter is highly dependent on assumed import demand elasticities, which have been subject to much debate. While the estimates applied here have been generally accepted across a broad range of simulations (see Dixon and Rimmer forthcoming), a change in the value of the elasticity could change the nature of these results.

[5] Demographic factors are as defined in chapter 3. They include measures of changes in the number of households and changes in the size of the labour force.

This finding is consistent with expectations under the SBTC hypothesis. That is, technology favours skilled over less skilled workers. In the textile industry, it appears to be in the form of 'harm reduction' in that it served to lessen skilled labour employment declines.

As described in chapter 3, *other* is a catch-all for changes in such variables as government spending, capital stocks, and inventory changes. These factors actually benefited less skilled labour over skilled labour, marginally reducing the relative gains of skilled workers.

Finally, changes in the *wages* experienced by the two types of workers indicate a movement away from skilled labour. The wages of less skilled workers declined in this industry in the period under review, serving to reduce employment losses from what they otherwise might have been. This outcome is consistent with the trade hypothesis.[6] A reduction in demand would reduce wages and, generally speaking, act to mitigate the decline in the employment of less skilled workers. The wages of skilled workers rose, serving to reduce their employment. This increase in skilled workers' wages is predicted under the SBTC hypothesis. Together, changes in wages had a negative effect on the change in employment of skilled workers.

The results show that the two most significant factors influencing the change in the employment of skilled relative to less skilled workers were changes in technology and changes in wages. Wage changes do not explicitly support either hypothesis. The change in the trade factors, for the most part, provide strong support for the trade hypothesis. The outcome appears to be more consistent with SBTC. That is, technological change, across several measures, has increased the demand for skilled workers.

Other business services

As in most industrialised countries, the majority of the Australian workforce is employed in the service sector. This sector accounts for over 65 per cent of all industries' gross value added. Other business services includes businesses such as legal and accounting services, plant and hire leasing. According to the Australia Bureau of Statistics (ABS), business services were the third largest employing industry in Australia, following Retail and Manufacturing.[7] As shown in figure 3.3, this industry experienced an increase in both labour and capital spending between 1987 and 1994. Capital spending growth was second only to personal services.

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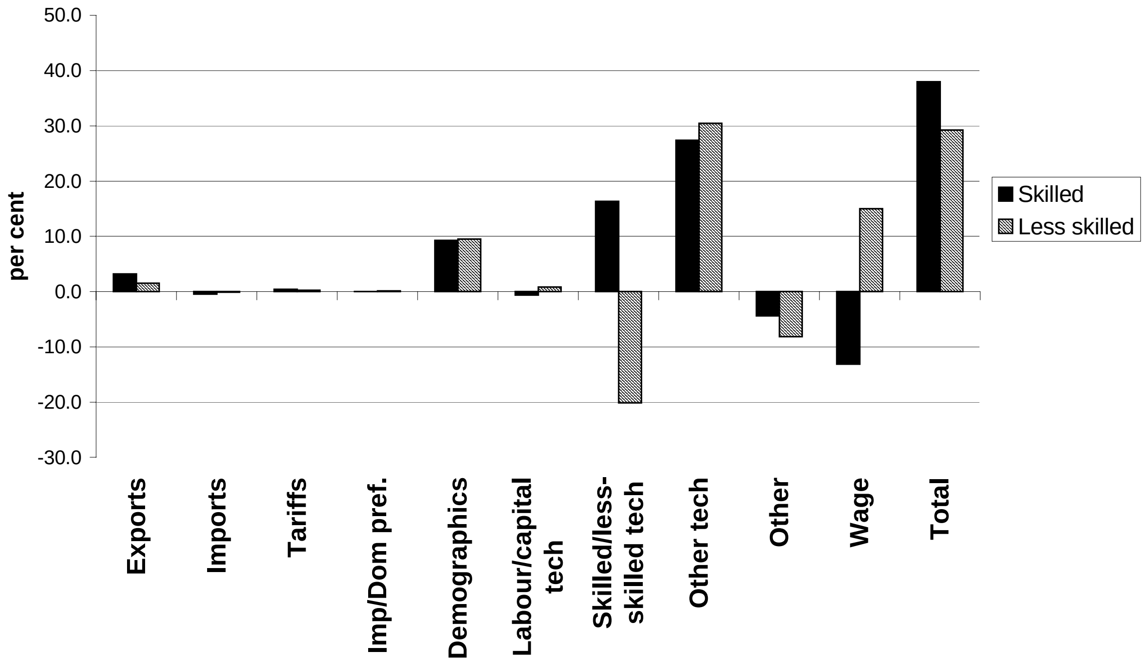
[6] However, a fall in less skilled workers' wages is not inconsistent with outcomes implied by SBTC, if changes in technology have led to a reduction in demand for these workers.

[7] Figures taken from AusStats, 2001, http://www.abs.gov.au/ausstats (accessed 11, April 2001).

Figure 4.2 presents the same decomposition of factors as was deemed in chapter 3 to explain the change in employment patterns in the other business services industry. Between 1987 and 1994, employment of skilled labour increased by 38 per cent while less skilled worker employment rose by almost 29 per cent. The increase in employment of skilled labour relative to less skilled labour is over 8 per cent.

Figure 4.2 **Factors contributing to the change in employment, Other business services**[a]
1987–1994



[a] Simulation results decomposing the contribution of each factor to the percentage change in employment for each type of labour.

Data source: PC estimates using a modified version of the MONASH model.

In this industry, none of the trade factors plays a significant role in explaining changes in employment.[8] Changes in *demographics*, however, do contribute positively to employment growth in both types of labour. Indeed, this change slightly favours less skilled workers over skilled workers. As discussed in chapter 3, demographic changes may reflect the underlying nature of employment growth in

[8] While other business services may not be directly traded, per se, trade factors may affect outcomes in this industry in so much as changes in export demand and import prices play a role in determining incomes and choices of products and services in the economy as a whole.

many of the services industries. This is because part-time employment tends to be over represented in occupations classified as less skilled (Wooden 1998).

Changes in technology showing a preference for the use of capital over labour (*labour/capital tech*) appear to favour less skilled workers and reduce, albeit slightly, the employment of skilled workers. This result may stem from the type of capital put in place. As outlined in chapter 3, in some service industries, capital investment, for example new call centres, may be complementary with less skilled occupations. Thus, expansion in capital associated with this type of technological change might be biased toward the use of less skilled workers.

Technical change affecting a firm's choice between skilled and less skilled workers (*skilled/less-skilled tech*) appears to have contributed positively to the employment growth of skilled workers and negatively to that of less skilled workers. This is consistent with SBTC in that the relative employment of skilled workers has improved. Other technology factors (*other tech*), contributed strongly to an increase in employment in this time period in other business services. However, unlike the textile industry, its influence served to increase both types of employment.

Also in contrast to the textile industry, other technology change benefited less skilled labour relative to skilled labour.[9] Again, this outcome may be influenced by part-time employment being over represented in less skilled occupational classifications. Broader technological changes affecting all factors of production, not specifically labour, favour less skilled workers in the other business services industry. In textiles, these forces were labour reducing. Thus, while technical change specific to labour input (s*killed/less-skilled tech*) supports the SBTC hypothesis, broader measures of technical change (*other tech*) do not.

Wholesale/retail trade

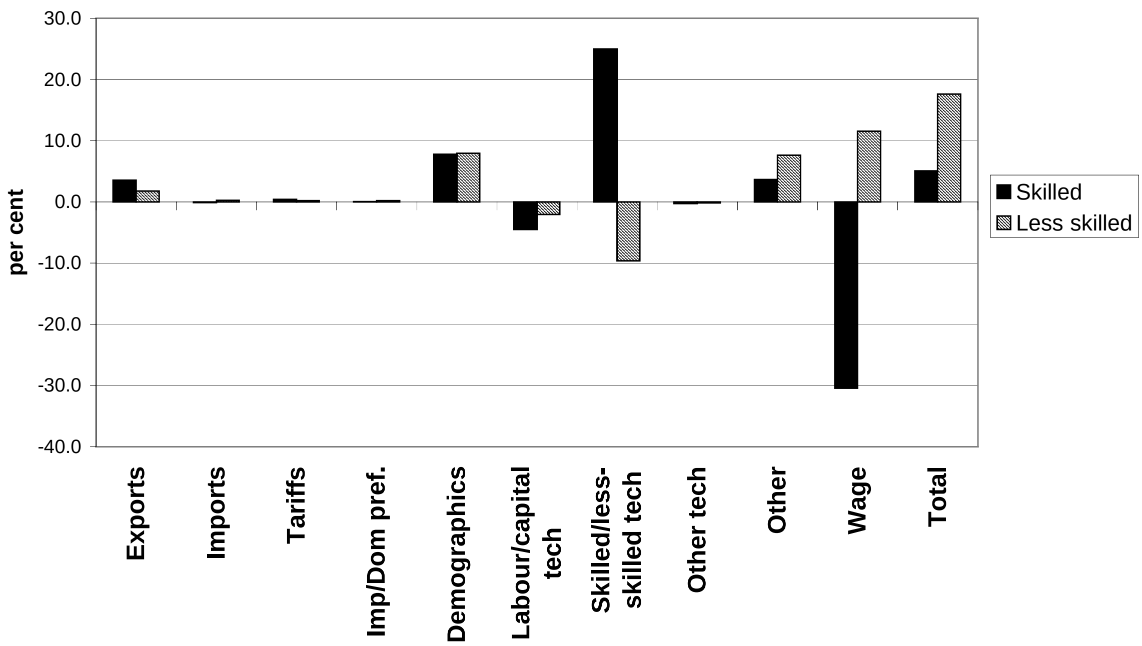
The final industry grouping examined is the wholesale/retail trade industry. This industry has been, and is expected to continue to be, one of the fastest employment growth industries in the economy (Adams and Meagher 2000). Overall, between 1987 and 1994, its total employment grew by almost 20 per cent. Skilled worker employment grew by 11 per cent while the employment of less skilled workers grew by over 23 per cent. Thus, relative skilled worker employment declined in this industry by 12 per cent.

9 Other technical change includes factors affecting an industry's use of all primary factors, separate from those influences captured by the skilled/less-skilled technical change and labour/capital technical change variables.

As shown in figure 4.3, most trade factors show virtually no effect on changes in employment of skilled or less skilled labour in the wholesale/retail trade industry grouping.[10] *Exports* contribute positively to both, slightly favouring skilled workers. *Demographics*, like other business services, positively influenced employment growth. However, there is no differential effect. Thus, this factor does not explain the relative change in employment observed in this industry.

The change in technology favouring the use of capital has a larger effect in this industry grouping than in the others examined. This is due, in part, to capital's larger share in total costs, relative to the other industries examined. The capital-related technical change has a negative effect on both types of labour, though more for skilled than less skilled. Again this outcome may stem from the type of capital employed. In this industry it appears that less skilled worker tend to be hurt less than skilled workers by this factor.

Figure 4.3 **Factors contributing to the change in employment, Wholesale/retail trade[a]**
1987–1994



a Simulation results decomposing the contribution of each factor to the percentage change in employment for each type of labour.

Data source: PC estimates using a modified version of the MONASH model.

[10] See footnote 8.

There is a larger positive impact on *skilled/less-skilled technical change* on employment of skilled workers and a smaller negative effect on less skilled in this industry grouping than in the two previously presented. The same pattern is observed in *wages*. Where skilled worker employment increased due to the shift in technology, changes in wages served to reduce these gains. As opposed to the other two industries examined, in the wholesale/retail industry grouping wage changes more than offset the technology shift, creating a net negative effect on skilled worker employment. The reduction in less skilled worker employment due to the *skilled/less-skilled technology change* variable is smaller than the positive shift coming from wage changes. The final outcome is a decrease in the relative employment of skilled workers in the wholesale/retail trade industry grouping.

As opposed to other business services, other technical change (*other tech*) plays almost no role here. Two trends affecting this industry may help explain this result. These are the trend in increased part-time employment and the increase in trading hours seen during this period. These trends have led to increases in jobs which are more often found in less skilled occupations, thus insulating these workers from broader technology change effects favouring skilled workers.

4.2 Summary

Overall, this analysis highlights that while broad trends at the economywide level exist at the industry level, the driving forces behind those trends differ between industries.

Textiles experienced a rise in relative skilled employment but this is due to the fact that total skilled employment fell less than less skilled employment. Technology effects were primarily felt through the *skilled/less-skilled technical change* measure and this served to reduce skilled workers' job losses.

Other business services also experienced a rise in relative skilled employment, but contrary to textiles, this was due to the superior growth in the employment of these workers. Also unlike textiles, technological effects from sources other than those strictly dealing with labour played a large role in skilled worker growth. Consistent with outcomes in textiles, changes in wages reduced gains in skilled worker employment relative to less skilled. But the net result (between changes in technology and changes in wages) was a gain in relative skilled worker employment.

In the wholesale/retail industry grouping, less skilled workers gained employment relative to skilled workers. The technical and wage changes dominate the contributing factors. No other technological factors play a significant role. However, as opposed to both textiles and other business services, the gains to skilled worker employment due to the *skilled/less-skilled labour technical change* variable were more than offset by wage increases leading to a relative reduction in their employment.

Looking at the three industries, the broad results favour the SBTC hypothesis over the trade hypothesis. While some anomalies exist (such as other technical change slightly favouring less skilled workers in other business services) the general outcomes are consistent with those expected under SBTC. That is, technological changes were biased in the employment of skilled workers. Trade factors played only a minor role.

5 Summary of findings

The findings outlined in the previous chapters support the SBTC hypothesis over the trade hypothesis as an explanation for the changing employment patterns in the Australian economy, as investigated in the 1987 to 1994 period. While this is consistent with previous evidence on this topic, the findings presented here are more robust, given the nature of the method employed and its more comprehensive approach.

5.1 Summary

Chapter one outlines four limitations noted in the literature about the existing evidence on earnings inequality. These limitations point to the need to consider changes across all sectors of the economy, distinguish between types of technical change, model wages and technology simultaneously and capture the interrelationship between trade openness and technical change. Using a general equilibrium model, this paper attempts to address these issues.[1] The model distinguishes between types of technical change within a fully-specified general equilibrium model of the Australian economy, simultaneously solving for all unknowns.

Through a multisector general equilibrium model, technical bias in the demand for skilled workers is shown to be pervasive across the economy. That is, with very few exceptions, this trend has affected all industries. The existence of a technical change bias in the use of skilled workers is found regardless of existing relative labour use (ie skilled or less skilled intensive industries). It can thus be argued that the shifting labour demand is not a symptom of differentials between sectors, but rather movements within sectors.

The MONASH model allows for a distinction to be made between certain types of technological change: technological change affecting overall production methods; that affecting the choice between capital and labour inputs (examining the capital embodiment or capital deepening arguments); and that specifically affecting the

[1] Attempts have been made to specifically correct for all of the issues raised, with the exception of the interrelationship between openness and technology. Implications of this interaction were inferred rather than explicitly accounted for.

choice between skilled and other types of labour. The fact that there appears to be a strong and consistent indication of a labour specific technology effect, regardless of assumptions made about a firm's underlying production function, is a strong indication of the role technological change has played in the determination of labour inputs in the Australian economy.

Individual industry results highlight the role different technology factors have on labour input decisions. For example, in the two service industries examined, broader technological changes, not specific to labour inputs, are shown to play a much larger role in determining relative skilled worker employment in other business services than in the whole/retail trade sector.

One area in need of further exploration is the interaction between openness and technical change. According to a study by the Business Council of Australia (Carnegie et al. 1993), the opening up of the Australian economy has stimulated a large change in competitive performance and has been a predominant driver of enterprise innovation. Thus, the extent to which changes in imports and exports have driven technological change still needs to be determined.

However, while increased openness may have led to enterprise innovation, it has also been blamed for the growth in earnings inequality in this country. Both of these trends have been linked to a change in the type of workers employed; namely an increase in the share of skilled workers. The results presented here provide little support for contentions that globalisation (as relates specifically to trade and tariff changes) has played a major role in the observed changes in the use of skilled or other types of workers. However, given that technical change has had a large influence on the change in exports (and, indirectly, imports), there may be an indirect effect at work. Thus, it could be possible that trade effects identified in the determination of relative labour use in the economy may have been actually transmitted through technological change.

These results are important for policy makers as they highlight the need to take a broader approach when determining what, if any, measures should be undertaken to combat the growing earnings inequality in Australia. For example, policies aimed at wages or other input-specific factors may not fully consider the dynamic interaction between inputs in the production process. Or, policy to 'combat' perceived threats from globalisation may cut off a strong source through which technology can increase productivity in the Australian economy.

5.2 Future research

Using a general equilibrium approach has controlled for the endogeneity problem between skilled workers and technical change (namely the feedback effects that occur from the existence of one or the other) by simultaneously estimating all factors effecting the demand for labour. Thus, it improves the estimation of technical change compared with traditional partial equilibrium approaches. The results are supportive for SBTC and less so for the trade hypothesis.

However, several issues remain outstanding. The first, as already noted, is the interaction between trade and SBTC. This study has not addressed the fact that trade may embody technical change. For example, imported capital equipment may embody technical change and the increasing need for firms to compete with imports may provide an incentive to adopt new technologies that are biased toward using a higher proportion of skilled labour. More detailed analysis of the possible interaction between these two forces is needed.

The second area worth further consideration is the measure of capital stock. As stated, an offshoot of SBTC is the capital-embodiment argument. It is argued that different types of capital embody technical change to varying degrees. Thus, changes in the types of capital put in place, and more importantly, capital's influence on the type of labour employed, is a reflection of technical change. A more detailed measurement of capital would enhance the model's ability to capture these effects.

A Historical and decomposition simulations with MONASH

A.1 Historical and decomposition modes of MONASH[1]

In MONASH, as in most CGE models, the starting point of the analysis is an 'initial solution'. This solution consists of an input-output table describing the links between all economic agents (firms, government, households) in a given year (1986-87 in the present case) and of a set of commodity and factor prices for that year. This detailed representation of the economy may be legitimately regarded as a model solution in that it satisfies all the economic theory and assumptions underlying the model: demands equal supplies; demands and supplies reflect utility and profit maximising behaviour; prices equal unit costs; and end-of-year capital stocks equal depreciated opening capital stocks plus investment.

From this initial solution, the economy undergoes changes over time. Thus, the economy in 1993-94 (the end period for this paper's analysis) incorporates different linkages, quantities and prices than existed in the initial period. Changes in some economic variables can be known readily, especially if they are measured by the Australian Bureau of Statistics (ABS) or the Australian Bureau of Agricultural and Resource Economics (ABARE). This is the case, for instance, for most macroeconomic aggregates such as GDP, employment, exports and imports and overall price indices. In some cases, detailed sectoral information on output and prices is also available. However, unless a complete input-output table is also available for the end year, the picture of the economy in 1993-94 will not be nearly as detailed as that available for 1986-87.

The role of the historical simulation is to 'fill the gaps' by inferring values for the missing variables which are consistent with what is already known about the economy. As an example, the model has to allocate total intermediate usage of a commodity among industries given known changes in total output, consumption and exports of that commodity. This allocation is done in accordance with the economic theory underpinning the model such as cost minimisation and unit cost pricing. The variables for which the change between 1987 and 1994 is already known are termed

[1] This section is based on Dixon et al. (2000) and on Dixon and Rimmer (forthcoming).

‘observable’ and are naturally exogenous. Combined with the model’s assumptions, these changes force solutions for the remaining unknown variables to be generated. These variables are endogenous.

Part of the solution generated by an historical run of MONASH is in the form of changes in prices and quantities for various commodities and factors of production. However, these changes are often not capable of explaining all the changes affecting an economy over a period. For example, it is possible for a commodity’s share of the household budget to have increased over the period, even though the model calculates that its equilibrium price has fallen (assuming no change in quantity). Therefore, some changes in economic variables can appear inconsistent with changes in prices and quantities recorded, or those the model calculates based on economic theory.

The key to these apparent inconsistencies lies in so-called ‘residual’ variables. As the name implies, these are variables that are required to reconcile all that is known about an economy and all that the model calculates on the basis of economic theory. They are generated automatically by MONASH so that the combination of endogenous and exogenous changes modelled are consistent with the initial solution for 1986-87 and the information known about 1993-94. While this is a mechanical process, these variables are given an economic interpretation, such as changes in technology, in consumer preferences, in domestic/import preferences, or in the international trading environment. This is valid in so far as, if technological change did occur, it would not be directly observable but would produce effects such as those ‘explained’ by the residuals.

However, it should be emphasised that there are alternative explanations for these residual variables. For example, changes in a commodity’s household budget share could be a reflection not of a change in taste or price, but of a change in the quality of a good. A case in point is mobile telephones; while their rapid uptake by consumers has increased household consumption of communication services, in spite of the apparently increasing prices for telecommunications, it would be erroneous to attribute this phenomenon to a change in consumer tastes favouring fixed-line telephone services. It is more correctly interpreted as consumption of a new commodity (‘mobile communication’) which remains classified under ‘communication services’.

A second caveat regarding the calculation and interpretation of residual variables is that their magnitude depends on the specification of the model. That is, residuals required to accommodate observed changes in prices and quantities will vary according to the model’s assumptions, degree of detail and flexibility of its functional forms. For instance, the amount of technological change required to ‘explain’ observed changes in the input structure of an industry will depend on whether constant or increasing returns to scale are assumed.

These caveats notwithstanding, the capacity of CGE models to measure hitherto unobservable variables such as technological change — defined as shifts in demands and supplies that are not accounted for by changes in input and output prices — is especially valuable in the context of testing the SBTC theory. This usefulness is compounded by the ability to measure the impact of these variables on the economy.

The role of unobservable variables can be measured precisely by switching the model from historical to *decomposition* mode and then imposing the changes in the unobservable variables (calculated in the historical simulation) on the model. Thus, in the decomposition simulation, the previously unobservable variables become exogenous and they are used to ‘shock’ the model (ie by telling their values to the model, the model calculates consistent values for all other variables). Conversely, some variables that were previously known (exogenous) are now made to vary in response to the shocks imposed (ie they become endogenous). As an example, this allows the impact of technological change in the automotive industry on GDP to be calculated.

Further, the historical/decomposition switch allows a *partitioning of history*, that is, the measurement of the contribution of each unobservable variable (or group of variables) to the historical movement in variables such as GDP, the trade balance or industry employment. The sum of all individual contributions equals the total change recorded in the variable of interest.

The switch between historical and decomposition simulations requires the reassignment of many model variables from exogenous to endogenous and vice versa. The main endogenous/exogenous swaps are given in table A.1.

Movements observed in macroeconomic and industry variables such as GDP and value added are partly explained by movements in unobservable variables. For instance, table A.1 shows that export volumes, which are exogenous in the historical simulation, are endogenous in the decomposition simulation. This means that the contribution of technological change (eg primary factor saving technical change in table A.1) to export growth can be measured.

For a more detailed discussion of the endogenous/exogenous variable sets in the historical and decomposition simulations using MONASH, see Dixon and Rimmer (forthcoming).

Table A.1 **Categories of variables in the historical and decomposition modes for standard MONASH**

Variable	*Historical Mode*	*Decomposition Mode*
Consumption by commodity	Exogenous	*Endogenous*
Shifts in household preferences	*Endogenous*	Exogenous
Total intermediate usage by commodity (deduced from information on outputs, imports and final usage)	Exogenous	*Endogenous*
Intermediate input-saving technical change	*Endogenous*	Exogenous
Employment and capital inputs by industry	Exogenous	*Endogenous*
Primary factor-saving technical change and capital/labour bias in technical change	*Endogenous*	Exogenous
Imports by commodity	Exogenous	*Endogenous*
Shifts in import/domestic preferences	*Endogenous*	Exogenous
Producer prices by industry	Exogenous	*Endogenous*
Rates of return on capital or markups on costs	*Endogenous*	Exogenous
Export volumes and f.o.b. prices	Exogenous	*Endogenous*
Shifts in foreign demand and domestic supply functions	*Endogenous*	Exogenous
Macro variables eg aggregate consumptions	Exogenous	*Endogenous*
Population	Exogenous	Exogenous
C.i.f. import prices in foreign currency	Exogenous	Exogenous
Policy variables eg tax and tariff rates and public consumption	Exogenous	Exogenous
Demands for intermediate inputs and margin services	*Endogenous*	*Endogenous*

Source: Based on table 2.1 (p. 12) in Dixon and Rimmer (forthcoming).

B Sector wage and employment data

This appendix describes the construction of the dataset containing time series on relative skilled/other employment and wages by sector between 1987 and 1994.

B.1 Data sources

Data on average weekly ordinary time earnings (AWOTE) and ordinary time (OT) hours worked are unpublished data from the ABS *Survey of Employee Earnings and Hours* (May). Their coverage is as follows:

- all employed persons (full time and part time);
- 1-digit level ASIC industry (except Agriculture, forestry and fishing);
- ASCO1 occupation; and
- year: 1987 to 1994.

B.2 Industry concordance

The original data are provided by broad (1-digit) ASIC sector. In order to ensure consistency with other time series used in the analysis, these data were concorded to a modified ANZSIC classification using the mapping shown in table B.1.

Table B.1 **ASIC/ANZSIC concordance for 1-digit sectors**

ASIC sector ➔	*Main corresponding ANZSIC sector(s)*[a]
B Mining	B Mining
C Manufacturing	C Manufacturing
D Electricity, gas and water	D Electricity, gas and water supply
E Construction	E Construction
F Wholesale and retail trade	F + G Wholesale and retail trade
G Transport and storage	I Transport and storage
H Communication	J Communication services
I Finance, property and business services	K + L Finance, insurance, property and business services
J Public administration and defence	M Government administration and defence
K Community services	N + O Education, health and community services
L Recreation, personal and other services	P + Q + H Cultural and recreational services + Personal and other services + Accommodation, cafes and restaurants

[a] Although this correspondence is thought to provide a reasonable basis for ascertaining broad industry trends, there are a number of individual activities that moved between sectors with the introduction of ANZSIC. Details of these moves are presented in ABS (1993).

Source: Based on ABS (*Australian and New Zealand Standard Industrial Classification*, 1993 Edition, Cat. no. 1292.0).

B.3 Relative employment and relative wage calculations

Two labour skill groups are defined, which contain the following ASCO1 occupations:

- *skilled workers*: managers, professionals, para-professionals; and
- *other workers*: tradespersons, clerks, salespersons and personal service workers, plant and machine operators and drivers, labourers and related workers.

Ordinary time employment for each skill category is then calculated by taking the employment-weighted average of the OT hours worked by all component occupations. For instance, the OT hours worked by skilled workers are the weighted average of those for managers, professionals and para-professionals, where the weights are the number of persons employed in each occupation in August of the same year (from the ABS *Labour Force Survey*). Once the weighted average for OT hours for each skill group is known, relative employment is calculated for each year by taking the ratio of the skilled workers figure and the other workers figure.

A similar procedure is used to calculate the change in relative skilled/other wages during the 1987–94 period. However, it is first of all necessary to calculate the hourly wage rate for each occupation. In each data cell, the value of AWOTE is divided by the number of OT hours to obtain the average hourly wage by sector and occupation in a given year. This hourly wage is then weighted by the number of OT hours each occupation has performed to yield the average hourly wage rate earned by each skill group. Results for the two groups are then divided to give the relative skilled/other wage in each year.

Table B.2 **Relative employment and relative wages of skilled workers**[a]

	1987	*1994*	*per cent change*
Hours worked			
B Mining	0.250	0.254	1.6
C Manufacturing	0.171	0.183	7.0
D Electricity, gas and water	0.361	0.552	52.9
E Construction	0.130	0.133	2.3
F Wholesale and retail trade	0.282	0.247	-12.4
G Transport and storage	0.130	0.120	-7.7
H Communication	0.238	0.267	12.2
I Finance, property and business services	0.511	0.554	8.4
J Public administration and defense	0.440	0.540	22.7
K Community services	1.551	1.528	-1.4
L Recreational, personal and other services	0.449	0.401	-10.7
Total	0.39	0.38	5.07
Hourly wage			
B Mining	1.41	1.54	9.2
C Manufacturing	1.64	1.98	20.7
D Electricity, gas and water	1.50	1.50	0.3
E Construction	1.46	1.84	26.0
F Wholesale and retail trade	1.58	1.95	23.4
G Transport and storage	1.65	1.79	8.5
H Communication	1.33	1.38	3.8
I Finance, property and business services	1.62	1.87	15.4
J Public administration and defense	1.65	1.61	-2.4
K Community services	1.56	1.66	6.4
L Recreational, personal and other services	1.34	1.63	21.6
Total	1.59	1.78	12.0

a Ratio based on observed data of skilled workers and other workers.

Source: PC estimates based on unpublished ABS data.

B.4 MONASH industry and sector classification

Below is a listing of the 113 MONASH industries and their corresponding sector.

Listing of MONASH industries

Number	*MONASH Industry*	*Sector*
1	Pastoral	Agriculture
2	WheatSheep	Agriculture
3	HighRain	Agriculture
4	NthBeef	Agriculture
5	MilkCattle	Agriculture
6	OthExport	Agriculture
7	ImportComp	Agriculture
8	Poultry	Agriculture
9	AgServ	Agriculture
10	Forestry	Agriculture
11	Fishing	Agriculture
12	IronOre	Mining
13	NFerrous	Mining
14	BlkCoal	Mining
15	OilGas	Mining
16	OthMin	Mining
17	MinServ	Mining
18	Meat	Manufacturing
19	Dairy	Manufacturing
20	FrtVeg	Manufacturing
21	OilFat	Manufacturing
22	Flour	Manufacturing
23	Bakery	Manufacturing
24	Confect	Manufacturing
25	Sea_Sugar	Manufacturing
26	SoftDr	Manufacturing
27	Beer	Manufacturing
28	OthDrink	Manufacturing
29	Tobacco	Manufacturing
30	Ginning	Manufacturing
31	Synthetic	Manufacturing
32	CottonYa	Manufacturing
33	WoolYarn	Manufacturing
34	TextileF	Manufacturing
35	Carpets	Manufacturing
36	Canvas	Manufacturing
37	Knitting	Manufacturing
38	Clothing	Manufacturing
39	Footwear	Manufacturing
40	Sawmill	Manufacturing
41	Panels	Manufacturing

42	Fittings	Manufacturing
43	Furniture	Manufacturing
44	PulpPaper	Manufacturing
45	BagsBoxes	Manufacturing
46	Sanitary	Manufacturing
47	NewsBooks	Manufacturing
48	CommPrint	Manufacturing
49	Fertilisr	Manufacturing
50	BasicChem	Manufacturing
51	Paints	Manufacturing
52	Pharmacy	Manufacturing
53	Soaps	Manufacturing
54	Cosmetics	Manufacturing
55	Explosive	Manufacturing
56	Petrol	Manufacturing
57	Glass	Manufacturing
58	ClayProd	Manufacturing
59	Cement	Manufacturing
60	Readymix	Manufacturing
61	Pipes	Manufacturing
62	Plaster	Manufacturing
63	IronSteel	Manufacturing
64	NFerrous	Manufacturing
65	Structurl	Manufacturing
66	SheetMetl	Manufacturing
67	Wire	Manufacturing
68	MotorVeh	Manufacturing
69	Ships	Manufacturing
70	Trains	Manufacturing
71	Aircraft	Manufacturing
72	SciEquip	Manufacturing
73	Electron	Manufacturing
74	HousAppl	Manufacturing
75	ElectEq	Manufacturing
76	AgMach	Manufacturing
77	ConMach	Manufacturing
78	ManuMach	Manufacturing
79	Leather	Manufacturing
80	Rubber	Manufacturing
81	Plastic	Manufacturing
82	Signs	Manufacturing
83	SportEq	Manufacturing
84	Electrcty	Electricity, gas and water
85	Gas	Electricity, gas and water
86	Water	Electricity, gas and water
87	Resident	Construction
88	OthBuild	Construction
89	Wholesale	Wholesale and retail trade
90	RetailTrd	Wholesale and retail trade

91	MechRep	Transport and storage
92	OthRepair	Transport and storage
93	RoadTrans	Transport and storage
94	RailTrans	Transport and storage
95	WaterTran	Transport and storage
96	AirTransp	Transport and storage
97	TransServ	Transport and storage
98	Communic	Communication
99	Banking	Finance, property and business svc
100	NonBank	Finance, property and business svc
101	Investm	Finance, property and business svc
102	Insurnce	Finance, property and business svc
103	OthFinan	Finance, property and business svc
104	Dwelling	Finance, property and business svc
105	PubAdmin	Public administration and defence
106	Defence	Public administration and defence
107	Health	Community services
108	Educate	Community services
109	Welfare	Community services
110	Entrtain	Recreational, personal and other svc
111	Hotels	Recreational, personal and other svc
112	PerServ	Recreational, personal and other svc
113	Other	Recreational, personal and other svc

C Functional form

C.1 Introduction

The input demand functions that are standard in MONASH are re-specified to incorporate a translog formulation for labour demand. The new framework allows the standard constant elasticity of substitution (CES) labour demand function to be incorporated as a special case. This appendix shows the derivation of the translog demand specification as implemented in the version of MONASH used in this paper. The standard CES specification is also derived. Then follows a description of a nested version of these two specifications that is implemented in MONASH.

C.2 Translog[1]

To provide a more flexible form, allowing for varying cross-price elasticities (ie substitutes and complements), the translog function is used to represent the firms choice of labour and capital inputs. The demand for individual inputs can be obtained by assuming that the production function has a corresponding cost function which maximises output with the minimum use of inputs. It is from this cost minimising function that estimating demand equations can be obtained.

The translog unit cost function can be stated as follows:

$$\ln C = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \ln p_i \ln p_j \qquad \text{(C.1)}$$

where ln*C* is the cost per unit of output, *p* are the input prices and α_0, α_i, α_{ij}, are all parameters. Stated this way, the underlying production function is assumed to exhibit constant returns to scale.

To derive the input demand functions in percentage change form, the first step is to take the exponential of (C.1), thus:

[1] This derivation relies heavily on Dixon P., Parmenter B., Powell A. and Wilcoxen P., 1992, *Notes and problems in applied general equilibrium economics,* North Holland Press, pp. 133–37.

$$C(p) = \exp\left((\alpha_0 + \sum_{i=1}^{n} \alpha_i \ln p_i + \frac{1}{2} \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} \ln p_i \ln p_j \right) \qquad \text{(C.2)}$$

The cost-minimising factor demands are obtained by Shepard's lemma, which states that if *C(Y,p)* gives the minimum total cost of production, then the cost minimising set of factor demands is:

$$x_k = \frac{\partial C(Y, p)}{\partial p_k} \qquad \text{(C.3)}$$

again, assuming constant returns to scale, input demands can be stated as:

$$= \frac{Y \partial C(p)}{\partial p_k} \qquad \text{(C.4)}$$

Thus, differentiating (C.2) and substituting into (C.4) gives:

$$x_k = YC(p)\left(\alpha_k + \sum_j C_{kj} (\ln p_j)\right) / \, p_k \qquad \text{(C.5)}$$

In percentage change form (C.5) is:

$$x_k = y + c + \sum_j \left[\frac{C_{kj}}{\alpha_k + \sum_t C_{kt} \left(\ln p_t \right)} \right] p_j - p_k \qquad \text{(C.6)}$$

The lower case symbols *x, y, c* and *p* represent percentage changes in their respective upper case symbols. Next *c* needs to be substituted out of (C.6):

$$c = \sum_k \left[\frac{\partial C(p)}{\partial p_k} \frac{p_k}{C(p)} \right] p_k \qquad \text{(C.7)}$$

The elasticities of the unit cost function can be rewritten as the input shares in total costs:

$$\frac{\partial C(p)}{\partial p_k} \frac{p_k}{C(p)} = S_k \qquad \text{(C.8)}$$

where $S_k = \dfrac{p_k x_k}{YC(p)}$

Thus, substituting (C.8) into (C.7) gives:

$$c = \sum_k S_k p_k \qquad \text{(C.9)}$$

The cost shares of the translog unit cost function are:

$$S_k = \alpha_k + \sum_k \alpha_{kj} (\ln p_j) \qquad \text{(C.10)}$$

Substituting (C.10) and (C.9) into (C.6) gives the input demand functions:

$$x_k = y - \left(p_k - \sum_k S_{kj} p_j \right) \qquad \text{(C.11)}$$

where S_{kj} is the modified cost share:

$$S_{kj} = S_j + \left(\frac{\alpha_{kj}}{S_k} \right) \qquad \text{(C.12)}$$

As for the CES production function, if prices (or relative prices) are unchanged, then the volume of input changes by the same percentage as output reflecting the assumption of constant returns to scale. However, unlike for the CES, the translog function allows for the complementarity between inputs, hence some of the weights in (C.11) may be negative. If α_{ij} is sufficiently negative, then the modified cost share S_{kj} will be negative and an increase in p_j will reduce the demand for input k.

C.3 Constant elasticity of substitution

The MONASH model uses the percentage change form of the input demand functions. In deriving this form of the demand functions, it is usually preferable to linearise the first-order conditions of the production function and then derive the input demand functions, rather than deriving the input demand functions and then linearising them.

The percentage change form of CES is[2]:

$$p_k = \lambda + (1+\rho) y - (1+\rho) x_k \qquad \text{(C.13)}$$

where (also in percentage change):

$$y = \sum_k S_k x_k \qquad \text{(C.14)}$$

2 For a formal derivation of the CES function, and in a general equilibrium context, see Dixon et al. (1992, p. 142–148).

and $S_k = \frac{\delta_k X_k^{-\rho}}{\sum_i \delta_i X_i^{-\rho}}$ (C.15)

By re-arranging (C.13):

$$x_k = -\sigma p_k + \sigma\lambda + y \qquad (C.16)$$

where σ is defined as:

$$\sigma = 1/(1+\rho) \qquad (C.17)$$

The elasticity of substitution, σ can be derived from the marginal products of the factors of production.[3] The elasticity of substitution between any pair of inputs is constant.

By substitution using (C.16) and (C.14) leads to:

$$\lambda = \sum_k S_k p_k \qquad (C.18)$$

Finally, substituting (C.18) into (C.16) provides the percentage change form for the input demand functions:

$$x_k = y - \sigma(p_k - \sum_{i=1}^{k} S_i p_i) \qquad k = 1,\ldots n \qquad (C.19)$$

These input demand functions state that if prices are unchanged, all input volumes, x_k change by the same percentage as output, y. If the price of input k rises, with all other input prices fixed, then the use of input k will fall relative to output by a factor dependent on the elasticity of substitution, σ.

C.4 Implementation in MONASH

Reiterating the two input demand functions for the CES and the translog functions are restated:

$$x_k = y - \sigma(p_k - \sum_{i=1}^{k} S_i p_i) \qquad \text{CES} \qquad (C.19)$$

[3] For a derivation of the elasticity of substitution, see Chiang (1984 p. 426–8).

$$x_k = y - \left(p_k - \sum_j S_{kj} p_j \right) \qquad \text{translog} \qquad \text{(C.11)}$$

These two sets of input demand functions are implemented in the MONASH code so that it is trivial to switch between the two forms. An input demand function nesting both of the above functions is shown below:

$$x_k = y - \sigma\left(p_k - \sum_j S_{kj} p_j \right) \qquad \text{(C.20)}$$

where as in (C.12) $S_{kj} = S_j + \left(\frac{\alpha_{kj}}{S_k} \right)$

To recreate the translog function, it is simply a matter of setting σ to one. To recover the CES, the α_{kj}/S_k term in (C.19) reduces to zero and S_{jk} = S_j. The relationship between α_{kj} and the elasticity of substitution between the inputs is given by:

$$\eta_{kj} = 1 + \frac{\alpha_{kj}}{S_{kj}} \qquad \text{(C.25)}$$

These Allen elasticities of substitution between demand inputs are commonly estimated at the mean value of S_{kj}. To recover the CES production function, the elasticities of substitution, η_{kj} are set to one. This means that α_{kj} equals zero and (C.12) reduces to $S_k = S_j$. Then the σ can be set to the appropriate CES value.

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