

4 Firm level evidence: effects of ICTs on performance

This chapter uses firm-level data from the BLS (described in chapter 3) to examine two key issues concerning the influence of computer use on firm performance:

- Has computer use raised the productivity of Australian firms and contributed to economic growth?
- Was computer use complemented by other factors in attaining productivity improvements?

To address these issues this chapter first outlines the association between computer use and labour productivity of firms. Section 4.2 then overviews the analytical framework and methodology used to analyse the impact of computer use on multifactor productivity (MFP) growth. This is followed by sections 4.3 and 4.4 which report first, results concerning the relationship between computer use and MFP growth and, second, the likely interaction between computer use and other factors. This chapter focuses on the eight industry sectors analysed in detail in chapter 3 (section 3.4, appendix A).

4.1 Characteristics of better performing firms

Using labour productivity as a measure of firm performance, data drawn from the BLS for 1996-97 indicate that firms using computers are on average more likely to have had higher labour productivity than those that did not (indicated by vertical productivity bars in figure 4.1). There was also a tendency for firms that had used computers longer to also have had higher labour productivity on average.

Figure 4.1 also reports information on the variability of labour productivity between firms within each sector (measured as the standard deviation from the mean and shown by the vertical lines). This information shows that variability is large in all sectors relative to the mean and it also shows significant differences between sectors. For example, variation in labour productivity between firms in the Construction, Transport & storage and Property & business services sectors appears to have been greater than for firms in other sectors.

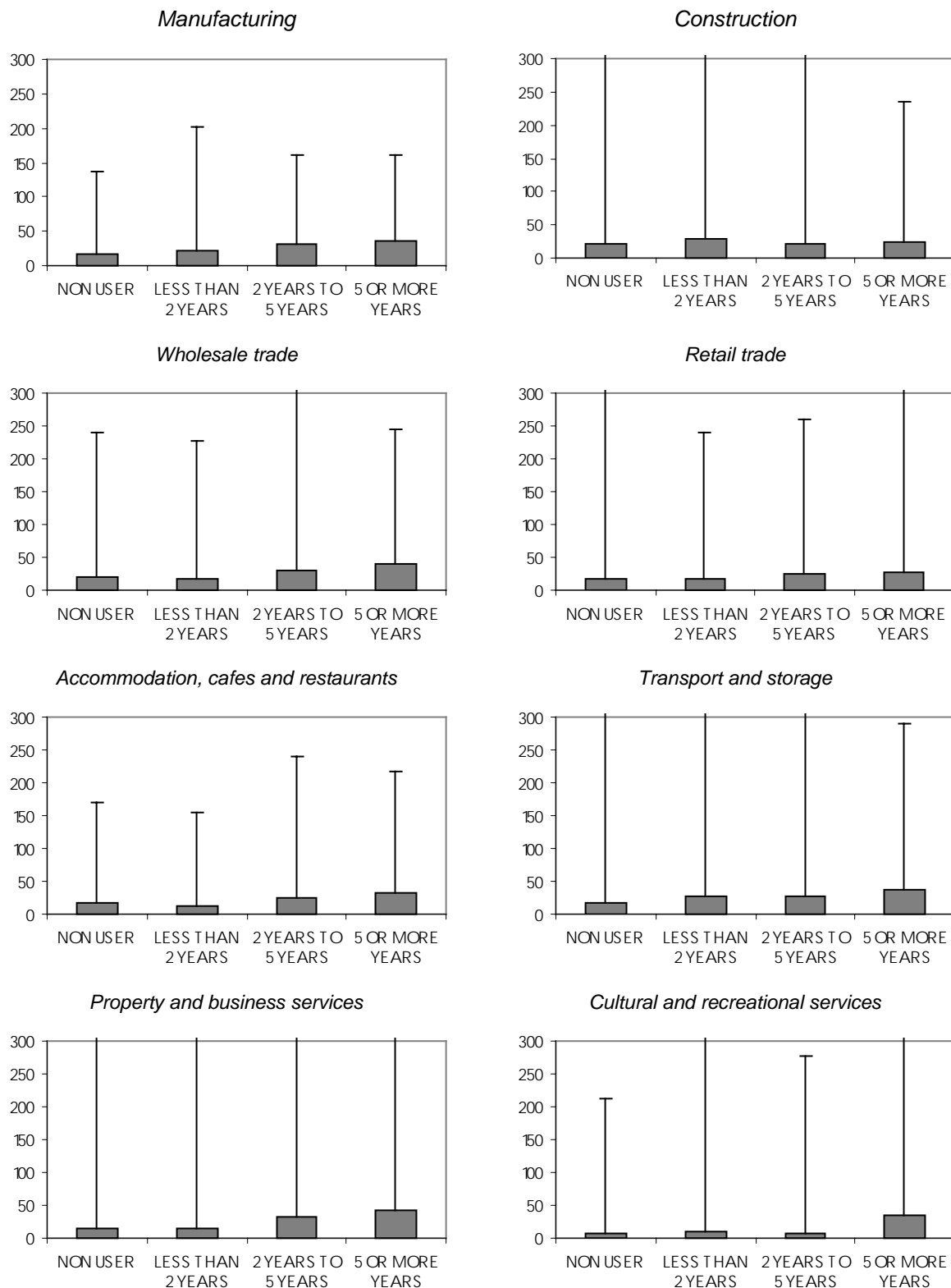
The BLS also provides information on whether or not firms made use of a number of computer-based functions. Figure 4.2 reports the relative productivity of users and non-users of computers plus three functional categories — Internet access, Web presence and online marketing. In four of these sectors — Manufacturing, Wholesale trade, Transport & storage and Property & business services — users of each category had higher labour productivity than the non-users in 1996-97. For remaining sectors, the relationship between use and non-use was mixed with BLS data suggesting the labour productivity was higher for users in some categories but lower for others (eg Construction and Retail trade). Again, there was very high variability (not reported in figure 4.2) between firms in each ICT use category.

When firms are ranked according to their labour productivity to form 'productivity quartiles', proportionately more firms in the highest quartile were computer users or had Internet access and/or a Web presence than in other quartiles (figure 4.3). However, because of the substantial variability in the level of labour productivity between users and non-users, there is no simple progressive relation across quartiles that can be applied to each sector. For example, for Manufacturing, the relationship between the incidence of firms using computers and productivity appears strongly positive. On the other hand, for Retail trade, the proportion of firms using computers in the first and second productivity quartiles is similar. And for Accommodation etc. more firms in the lowest productivity quartile were found to use computers than in some higher productivity quartiles.

Because of the high variation in labour productivity for both computer users and non-users, it is difficult to use sectoral averages and simple comparisons of performance to draw inferences about the influence of computer use on productivity. Also, firms that adopt ICT may already have been the more productive firms. Thus, there may be either no relationship between the length and intensity of use and productivity, or a more complex analysis is necessary to disentangle the relationship if one exists. Regression analysis has therefore been used to examine in more depth the complex relationship between computer use, MFP and labour productivity growth, after controlling for other factors that may also influence labour productivity growth.

Figure 4.1 Labour productivity by duration of computer use, 1996-97

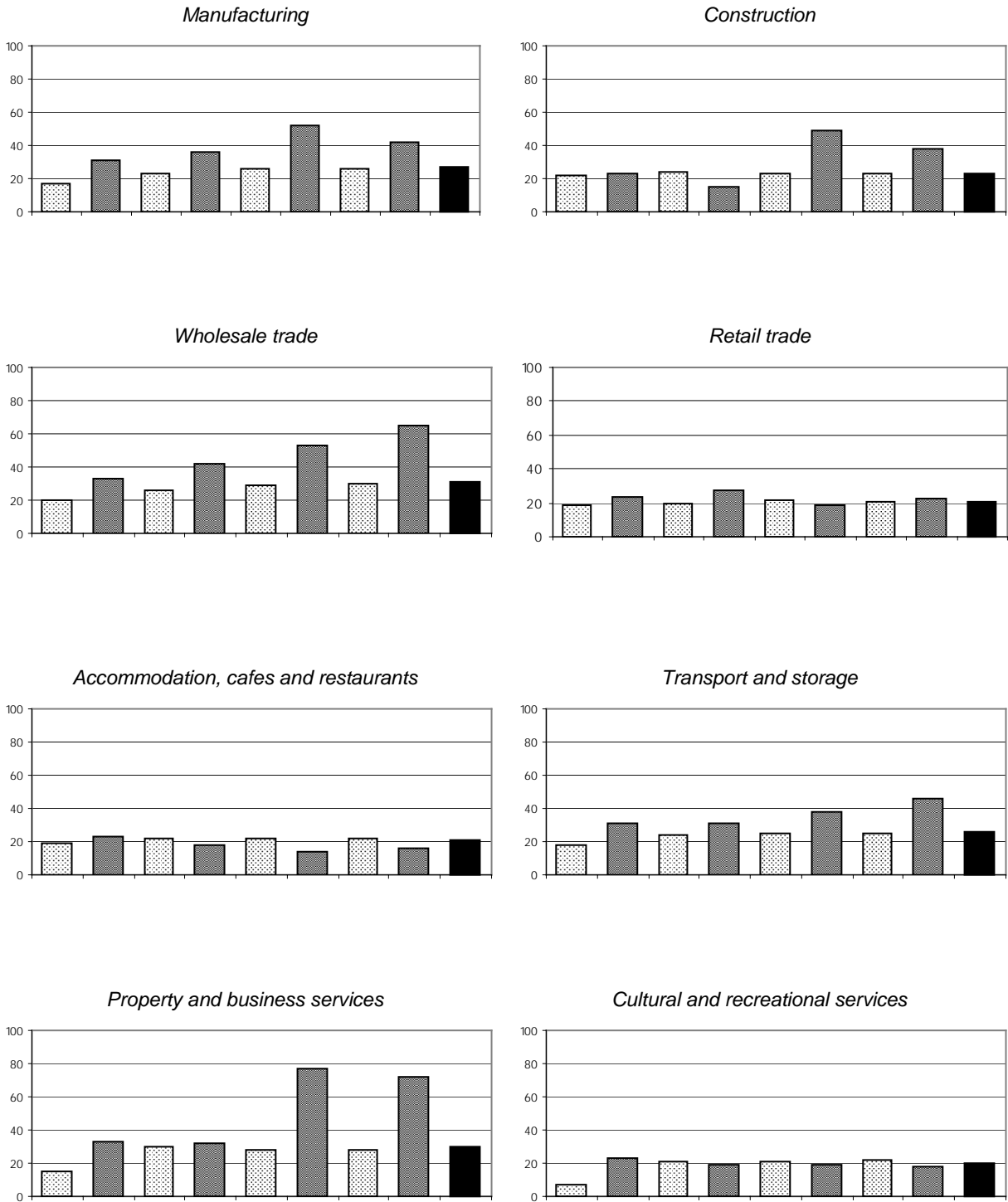
Average (bars), Standard deviation (lines), \$000 value added per person



Source: ABS (Business Longitudinal Survey, 1994-95 to 1997-98 Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

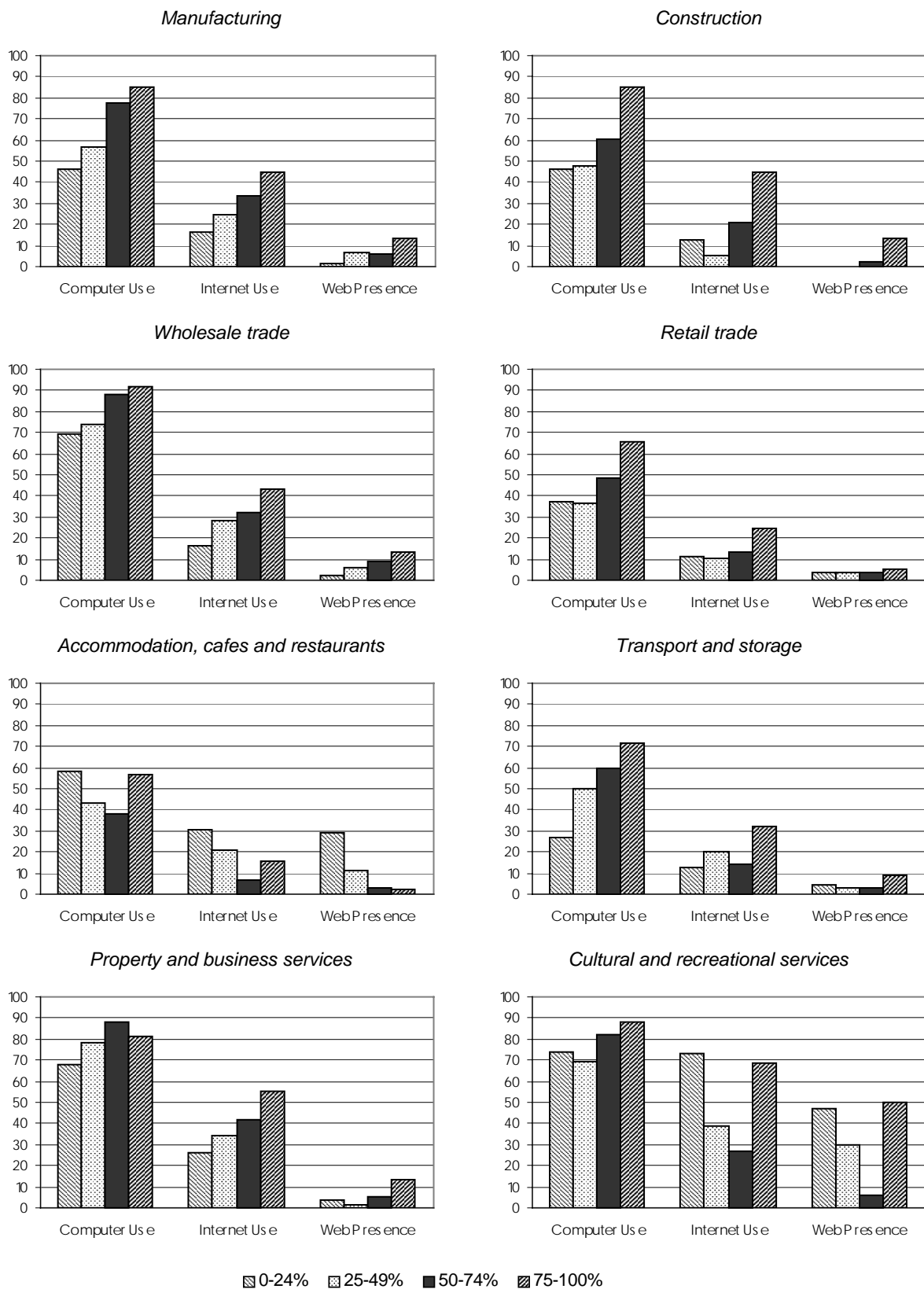
Figure 4.2 Labour productivity by functional use of ICT, 1996-97

Average (bars), \$000 value added per person



Source: ABS (Business Longitudinal Survey, 1994-95 to 1997-98 Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

Figure 4.3 ICT use by labour productivity quartiles, 1996-97
Per cent



Source: ABS (Business Longitudinal Survey, 1994-95 to 1997-98 Cat. no. 8141.0.30.001; special tabulations by the ABS based on the Main Unit Record File (MURF)).

4.2 Framework for analysis of the influences of ICTs on firm productivity

Overview of methodology

The regression model adopted in this study is based on a production function approach derived from a growth framework in which technological progress shows up as a new basic innovation or general purpose technology (box 4.1). Viewing ICT as a new general purpose technology provides a rationale for ICT contributions to MFP growth to be analysed in this general framework. It also enables the introduction of ICT to be considered as part of a continuum of change contributing to growth rather than as an ad hoc technological disturbance.

For empirical analysis, the underlying estimation model is expressed in its labour intensive form.

Formally, labour productivity is defined as $y = \frac{Y}{L}$ where Y is the level of value added output²⁵

and L is the level of labour inputs. Similarly, capital inputs per unit of labour input are defined as

$k = \frac{K}{L}$ where K is the level of capital inputs. Secondly, the model is specified in changes to

provide a basis for the inclusion of growth dynamics in the analysis. The basic labour productivity growth equation including ICT is:

$$\dot{y} = \beta_0 + \beta_1 \dot{k} + \beta_2 ICT + \varepsilon \quad (4.1)$$

where the dot over y and k indicates the logarithmic change between years in labour productivity and capital intensity, respectively.²⁶ The coefficient β_1 is the elasticity of labour productivity with respect to a change in capital intensity. It is the empirical equivalent to the technological parameter $1 - \alpha$ in the theoretical model (box 4.1). $\beta_1 = 1 - \alpha$ would also be equal to the capital income share in output for firms characterised by constant returns to scale (CRS) with competitive pricing of inputs. Where there is a prior understanding that these conditions generally hold, the magnitude of the estimated β_1 provides a useful qualitative test on the specification of the estimated model.

β_2 represents the impact of ICT take-up on labour productivity growth and is a component of the measure ‘multifactor productivity’ growth which is the subject of traditional productivity analyses (and the focus of chapter 2 of this paper). A positive and statistically significant value would indicate that the take-up of ICT has contributed to MFP growth. β_0 represents the growth in labour productivity not accounted for by other factors. In traditional growth studies, β_0 would also provide an estimate of the MFP arising from all technological and organisational changes. However, as the contribution of ICTs to MFP growth is being separately estimated in this study, the definition of β_0 is differs from that of traditional growth accounting studies.

²⁵ This practice conforms to many other studies, for example Rogers and Tseng (2000), Atrostic and Nguyen (2001), Baldwin and Sabourin (2001), and Hempell (2002).

²⁶ That is, $\dot{y} = \log\left(\frac{y_t}{y_{t-1}}\right)$ and $\dot{k} = \log\left(\frac{k_t}{k_{t-1}}\right)$.

Box 4.1 **Outline of a model of technological change with an expanding variety of products**

One aspect of technological advance comes from basic innovations or new general purpose technologies that can be regarded as being embodied in conventional physical and human capital. A tractable way of considering this kind of technical advance is through models with an expanding variety of products introduced by Romer (1986, 1990) and outlined and discussed in Barro and Sala-i-Martin (1995, chapter 6). The basic product supply function aligned with these theoretical contributions and adopted for this study is:

$$Y_i = A_i L_i^\alpha (K_i)^{1-\alpha} N^\alpha$$

where $0 < \alpha < 1$, Y_i is output, L_i and K_i are labour and capital inputs, respectively, and A_i is technological progress and improvements in organisation other than that attributable to increased product variety. N represents technical progress through increased input variety and takes the form of an increase in the number of specialised inputs 'available' to firms.

As information on the number of varieties (N) and changes in this number (n) that underpin the expression of the theoretical model with an expanding variety of products is not directly observable, it is necessary to adopt simplifying assumptions and approximations to complete empirical models. In our study, we have replaced these theoretical variables with dummy variables which take a positive value when a firm is an ICT user and zero otherwise. This focuses the empirical model on the impact of ICT without reducing the generality of the framework.

This augmented Cobb-Douglas production function exhibits diminishing returns to individual inputs and constant returns for all inputs together. This specification provides a tractable way to emphasise that long-run growth arises from technological advance and to model one kind of endogenous technical change. The assumption of constant returns to scale also provides a useful benchmark against which empirical results can be evaluated.

The model of expanding product variety is appropriate for analysing the impact of breakthrough innovations, such as ICT, that provide a material increase in the number of input varieties. The model also suggests that if the diffusion of ideas from one country to another is rapid, then technologies in all countries would improve. This feature is particularly pertinent to Australia which has been predominantly a user of ICT hardware technologies rather than a developer and manufacturer.

The specification of the model was refined in a number of ways to complete two estimation models. First, a basic estimation model was specified in which:

- the ICT variable was decomposed into five components with four indicating the duration of ICT use to allow for non-linearities between the duration of use and MFP growth, and one indicating whether a firm has Internet access or not; and
- two variables were added to the model, one to account for conditional convergence in labour productivity towards a 'best practice' and a second to allow for a possible underlying relation between firm size and growth.

The basic model is specified more formally in box 4.2. Results from the implementation of the basic model are reported in section 4.3 below.

Box 4.2 Specification of the basic regression model

Formally, the basic estimation model can be written as:

$$\dot{y} = \beta_1 \log(y_{t-1}) + \beta_2 \text{Size} + \beta_3 \dot{k} + \beta_{4,1} \text{ICT_d1} + \beta_{4,2} \text{ICT_d2} + \beta_{4,3} \text{ICT_d3} + \beta_{4,4} \text{ICT_d4} + \beta_5 \text{netacc}$$

Where the variables \dot{y} and \dot{k} are defined in the text. The variable *size* is defined as full time equivalent employment (the BLS variable *_totfte*). The four duration of computer 'dummy' variables are: *ICT_d1* (the BLS variable *COMDUM1*) that has a value of one if a firm used computers for less than two years and zero otherwise; *ICT_d2* (the BLS variable *COMDUM2*) that has a value of one if a firm used computers for a 'shorter' period of time and zero otherwise (imputed for the years 1994-95 and 1995-96 on the basis of duration of use data collected in 1996-97 returns); *ICT_d3* (the BLS variable *COMDUM3*) that has a value of one if a firm used computers for between two and five years and zero otherwise; and *ICT_d4* (the BLS variable *COMDUM4*) that has a value of one if a firm used computers for five or more years and zero otherwise.

Because of data limitations, it was not possible to extend this methodology to Internet use or Web presence variables. In our analysis, therefore, account has been taken of the extension of the use of ICT, through these media with a single binary variable *_netacc* with a value of one for firms with Internet access and zero otherwise.

While the basic model explores the central relation between ICT use and growth, it does not elaborate on possible complementary relations between ICT use by firms and their level of skill (or human capital), innovation, business practices and organisational changes. It also does not take account of all information available from the BLS that may influence productivity growth in its widest sense. To take account of these influences the basic model was augmented in two ways:

- first, the ICT variables, in addition to being entered individually, were interacted with organisational and technical factors to take account of the proposition that for firms to achieve improvements through the use of ICT they must possess skill advantages, have business practices that enable the assimilation of knowledge about new technologies and undertake organisational change; and
- second, additional growth variables suggested by the literature were added as independent explanatory variables to control, as far as practicable, for firm specific productivity influence not accounted for other factors.

The specification of the augmented model is outlined in box 4.3. Results from the augmented model are reported in section 4.4.

Box 4.3 Outline of augmented model with ICT complements

Formally, the empirical model is augmented with other variables and computer use interaction variables as shown below. The dependent variable is the same as in the basic growth model — logarithmic change in labour productivity. The explanatory variables in the augmented model include:

A regression constant

$$\beta_0$$

The basic growth and ICT variables

$$\beta_1 \log(y_{t-1}) + \beta_2 \text{Size} + \beta_3 \dot{k} + \beta_{4,1} \text{ICT_d1} + \beta_{4,2} \text{ICT_d2} + \beta_{4,3} \text{ICT_d3} + \beta_{4,4} \text{ICT_d4} + \beta_5 \text{netacc}$$

Computer use interaction variables

$$+ \beta_{6,1} (\text{ICT_d1} * \text{wagerate}^2) + \dots, \\ + \beta_{7,1} (\text{ICT_d1} * \text{innova}) + \dots, + \beta_{8,1} (\text{ICT_d1} * \text{l1innovat}) + \dots, \\ + \beta_{9,1} (\text{ICT_d1} * \text{busprac}) + \dots, + \beta_{10,1} (\text{ICT_d1} * \text{l1buspra}) + \dots, \\ + \beta_{11,1} (\text{ICT_d1} * \text{busrebi}) + \dots, + \beta_{12,1} (\text{ICT_d1} * \text{l1busre}) + \dots,$$

where the variables interacted multiplicatively with each computer use dummy (*ICT_d*) are: the wage rate (squared) (*wagerate*²) to represent human capital; innovation experience and the lag of innovation experience (*innova* & *l1innovat*); an index reflecting the intensity of adoption of 6 advanced business practices and the lag of those business practices (*busprac* & *l1buspra*) and an index of the propensity of current and past year implementation of 11 major firm-specific organisational changes (*busrebi* & *l1busre*).

Other control variables

$$+ \beta_{13} \text{buslocs} + \beta_{14} \text{age} + \beta_{15} \text{l1newbus} + \beta_{16} \text{tolo} + \beta_{17} \text{randd} + \beta_{18} \text{expbi} \\ + \beta_{19} \text{unionme} + \beta_{20} \text{conout} + \beta_{21} \text{arrawar} + \beta_{22} \text{arrcont} + \beta_{23} \text{arrunre} + \beta_{24} \text{arrreg} \\ + \varepsilon_{it}$$

The variables included in this group are: the incidence of multiple locations (*buslocs*), firm age (*age*); new business status (*l1newbus*); type of legal operation (*tolo*); research and development (*randd*); export status of the firm (*expbi*); extent of union membership (*unionme*); incidence of contracting out activities previously done by own employees (*conout*); type of employment arrangements — awards (*arrawar*); individual contracts (*arrcont*); and unregistered & registered agreements (*arrunre* & *arrreg*).

Details about the definition of model variables are provided in appendix B while an outline of the rationale for including each item is set out in appendix C. Panel regression methods were used to estimate of the basic and augmented models. Appendix D outlines the econometric method used and choice of estimator and also canvases some key econometric issues relevant to the current study.

4.3 Growth effects of ICT use

Results for the basic model are presented in table 4.2. The results describing the impact of computer use on productivity growth are summarised in figure 4.4. This figure shows that:

- coefficients on computer use are generally positive and statistically relevant for all the eight sectors analysed; and
- the impact of computer use on firm productivity growth shows a clear dynamic pattern common between sectors. Under this pattern, the initial impact of computer take-up tends to be negligible (or a small negative/positive). As the duration of computer use increases, so do the positive effects on firm performance. Finally, after a period of adjustment of around five years, the productivity stimulus of computer take-up appears to have been largely completed with growth returning to 'normal'.

While the results show a clear dynamic pattern which conforms with the predictions of growth theory, they should be interpreted cautiously as they do not incorporate changes in the intensity of computer use and the variables for the earlier years in the survey period were imputed using information collected towards the end of the period (see above).

The regression results in figure 4.4 also indicate that Internet access typically had a positive and significant influence on productivity growth. (As mentioned above, available information did not support the analysis of time profiles for this aspect of computer use.)

The more detailed results reported in table 4.2 indicate that the:

- coefficients on lagged labour productivity ($\log(y_{t-1})$) are negative and significant, indicating that conditional convergence is implied by the firm-level data. The coefficient on that factor provides an indication of the adjustment period required to reach a new equilibrium following a change in capital intensity. The results suggest that adjustment halfway towards a new equilibrium would be: around three years for Construction;²⁷ four years for Wholesale and Retail trade; five years for Manufacturing, Transport & storage and Property & business services; six years for Accommodation, cafes & restaurants; and twelve years for Cultural & recreational services; and
- coefficients on growth in capital per unit of labour inputs (ie capital deepening, $kdot$) are generally of a similar magnitude to the capital share in value added, suggesting, in broad terms, the data are not inconsistent with the benchmark technology with constant returns to scale and competitively priced inputs. Nevertheless, the results for the Wholesale trade, Retail trade, Accommodation etc sectors appear to be upwardly biased (according to the CRS criterion) and Cultural & recreational services downwardly biased. Possible sources of bias include: sampling differences between the BLS and national accounts and aggregation bias; and firm restructuring and demand changes that occur simultaneously with investment decisions;²⁸
- coefficients on firm (employment) size ($size$) are negative and significant for four of the eight sectors analysed indicating that on balance, coordination costs may increase with size. Positive coefficients for the Manufacturing and Construction sectors, on the other hand, suggest that size provides some productivity advantage for these sectors.

²⁷ Calculated as $[-\ln(0.5)/-\ln(-0.638+1)/4]$ (Barro and Sal-i-Martin 1995, p. 37).

²⁸ In technical terms, the error term in the regression would be positively correlated with the change in capital intensity ($kdot$) for the Wholesale trade, Retail trade and Accommodation etc. and negatively correlated for Cultural & recreational services.

4.4 How other factors interacted with ICT use

This section extends the basic growth analysis to report results from the model augmented to take account of the impact of interactions between computer use and key firm characteristics, and to control for the influence of an extended range of other factors potentially influencing growth and outlined in section 4.2.

The results for the impact of computer use are summarised in table 4.3. Results for the general growth variables are repeated in this table as they were generally not sensitive to the changes in model specification considered. However, in the case of Wholesale trade, the coefficient on capital (*kdot*) aligned more closely with the national accounts capital-income share.

Table 4.3 shows that the impact of computer use taken alone tended to be of lower significance than in the basic model (table 4.2). This can be attributed to a tendency for the combined effect of computer use with firm characteristics (ie the interaction terms of the model) outweighing the effect of computer use alone. Nevertheless, the results also suggest that computer use alone still had a positive and significant impact on productivity growth particularly in the medium term (represented by *ICT_d2, d3*). Generally speaking, the inclusion of interaction effects in the analysis has indicated that the relation between the uptake of a new technology and productivity growth is more complicated than portrayed by the basic model.

Figure 4.5 explores this issue by comparing the contribution of computer use to productivity growth in the basic and augmented models. It repeats the contribution of computer use estimated from the basic growth model (dark line) (from figure 4.4). It also shows the estimated impact of computer use in combination with other selected factors (light line).

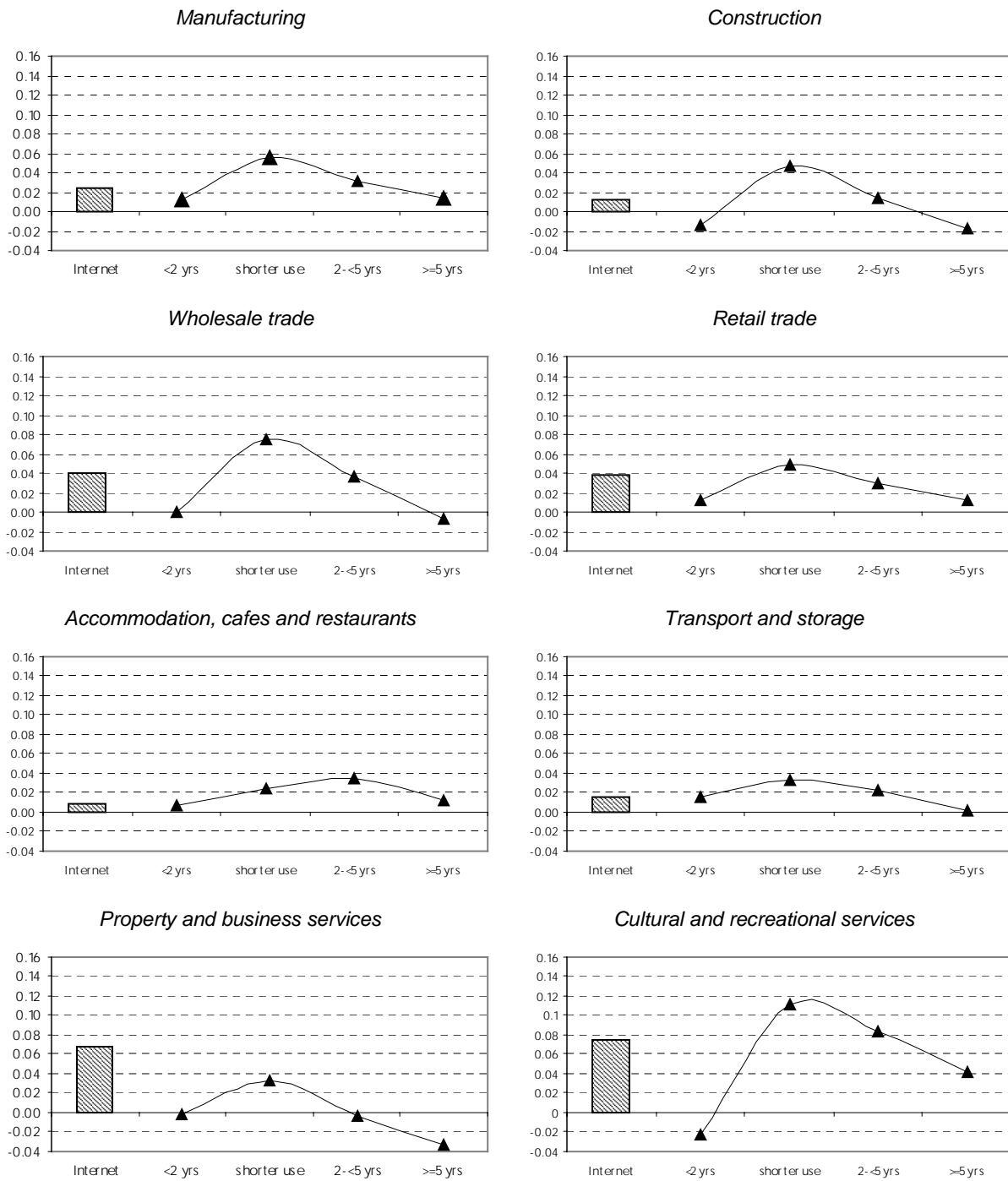
The main finding from this comparison is that the impact of computers inclusive of interaction effects generally lies *above* the impact of computer use alone. In addition, the combined analysis also indicates that the impact of other factors differs with the duration of computer use:

- firms using computers for less than two years appear to have little complementary association with innovation, skill and organisational changes for most sectors;
- the impact of computer use and complementary changes tends to generally taper off with the length of computer use;
- for the Manufacturing, Accommodation etc and Property & business services sectors, the dynamic pattern based on duration of computer use was maintained from the basic model.
- however, for some sectors the estimated dynamic pattern was modified, in particular:
 - for Construction and Cultural & recreation services the complementary changes appear to have had a substantial additional positive impact on productivity in the early stages of computer use;
 - for the Wholesale trade, Retail trade, Transport & storage sectors and Cultural & recreational services transition (or adjustment) costs appear to have been significant in periods following the commencement of computer use. These adjustment costs were identified with the reorganisation of firms as indicated by the total impact point (on light line) lying below the partial point (on dark line). For example, the Wholesale sector was subject to significant restructuring during the period, and it is possible that adjustment costs estimated in this simulation are reflective of widespread reorganisation of the sector (eg see Johnston et al. 2000).

Table 4.3 elaborates the relationship between computer use interactions and productivity growth. Some important findings reflected in this table include:

- a positive relation between the interaction of computer use and skill ($wagerate^2$) on productivity growth was found in all sectors. This relationship was generally maintained regardless of the duration of computer use;
- the interaction of computer use and the intensity of advanced business practices adopted by firms in the current and previous year, respectively (ie *_busprac* and *lbuspra*) typically had a positive and relevant impact on productivity growth in all but two sectors. Nevertheless, some evidence that interaction of advanced business practices also induced adjustment costs in certain circumstances is indicated by some negative coefficients. A similar picture emerged with the interaction of computer use with organisational change variables (*busrebi* and *lbusre*);
- while the link between computer use and ‘innovation’ (ie *innovat* and *linnovat*) is frequently mentioned in the literature, this relation is not widely evident in the current analysis. For example, the interaction of computer use and product innovative activity of firms was estimated to have had a positive relation with productivity growth for the Manufacturing sector but mixed relations elsewhere. This may suggest that the key forms of innovation relate to ‘input innovation’ in the form of organisational change and re-skilling. Input innovation in these forms would be covered by other factors in the model. It may also suggest that the relation between computer use, product innovation and productivity is more complicated than modelled.

Figure 4.4 Contribution of ICT to productivity growth^a — basic model
Percentage points



a Contribution of each ICT_d variable to average labour productivity growth evaluated at the BLS regression sample means.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

Table 4.2 Estimated impact of ICT on productivity growth — basic model

Regression coefficients, Dependent variable is change in labour productivity, unweighted estimates

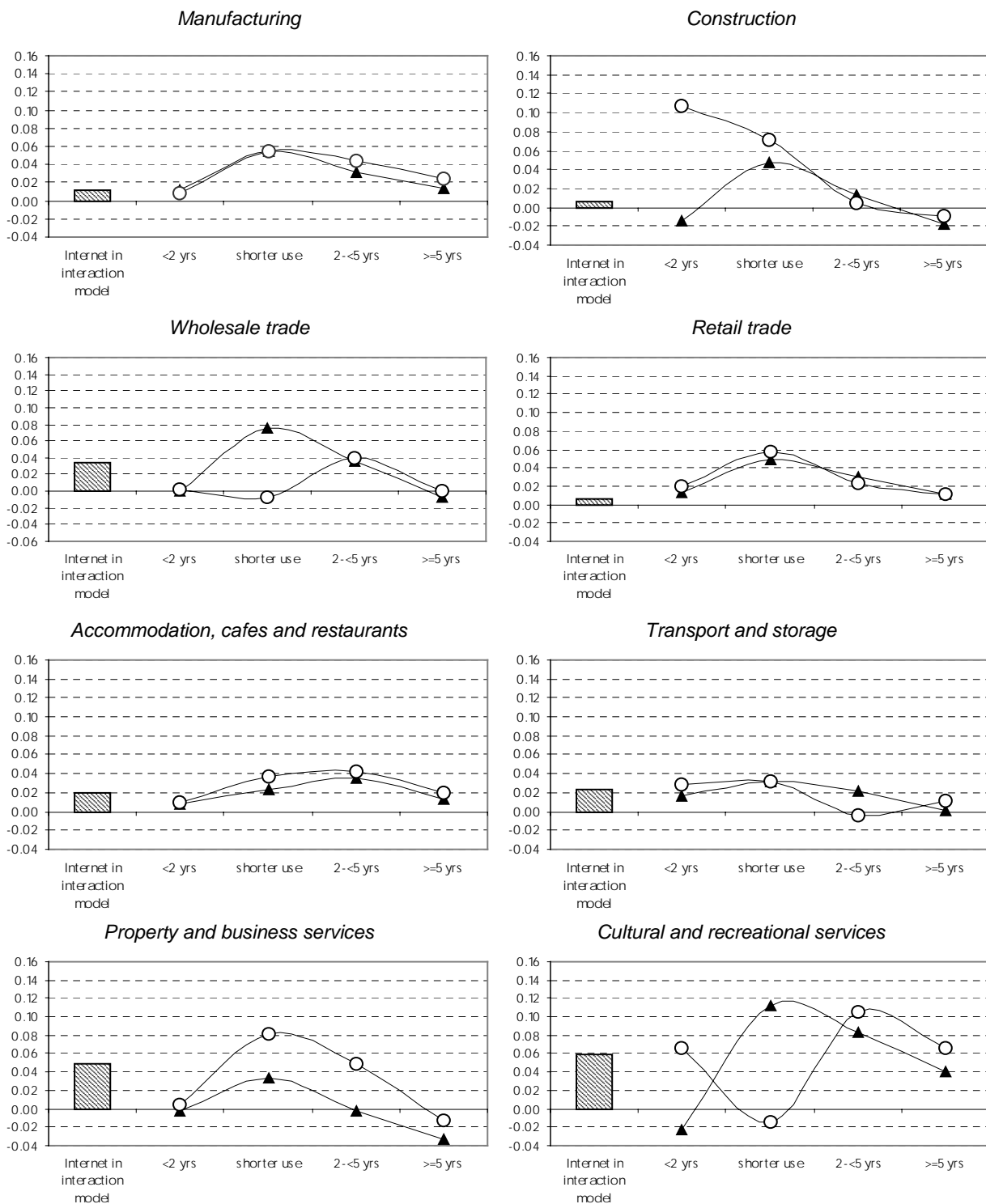
| | Manufacturing | Construction | Wholesale trade | Retail trade | Accommodation, cafes & restaurants | Transport and storage | Property and business services | Cultural and recreational services |
|---|---------------|--------------|-----------------|--------------|------------------------------------|-----------------------|--------------------------------|------------------------------------|
| Intercept | 1.498*** | 2.409*** | 1.815*** | 1.683*** | 1.333*** | 1.525*** | 1.756*** | 0.518** |
| Log(y_{t-1}) | -0.423*** | -0.638*** | -0.478*** | -0.48*** | -0.391*** | -0.415*** | -0.45*** | -0.224*** |
| k dot | 0.397*** | 0.272*** | 0.422*** | 0.385*** | 0.334*** | 0.390*** | 0.333*** | 0.297*** |
| Size ('00) ^b | 0.047* | 0.210* | 0.022 | -0.228*** | -0.199# | 0.087 | -0.004 | -0.232# |
| ICT_d1 (<2yrs) | 0.124*** | -0.095# | -0.005 | 0.124** | 0.071 | 0.131# | -0.025 | -0.148 |
| ICT_d2 (short) | 0.223*** | 0.319*** | 0.283*** | 0.202*** | 0.178# | 0.169# | 0.139# | 0.539** |
| ICT_d3 (2-5yr) | 0.130*** | 0.061 | 0.136** | 0.124*** | 0.187*** | 0.097# | -0.011 | 0.318* |
| ICT_d4 (5+ yrs) | 0.054* | -0.132# | -0.025 | 0.052# | 0.110# | 0.007 | -0.152 | 0.210# |
| Netacc | 0.064*** | 0.059 | 0.082*** | 0.072* | 0.051 | 0.065 | 0.132*** | 0.163# |
| Capital share | | | | | | | | |
| Australian national accounts ^a | 0.40 | 0.26 | 0.30 | 0.20 | 0.24 | 0.36 | 0.37 | 0.41 |
| Model summary | | | | | | | | |
| Panel model | One way RE | One way RE | One way RE | One way RE | One way RE | One way RE | One way RE | One way RE |
| BLS observations | 8077 | 1398 | 3375 | 2570 | 952 | 942 | 3615 | 565 |
| Model observations | 4503 | 623 | 1858 | 1299 | 477 | 432 | 1473 | 187 |
| Number of firms ^b | 1790 | 289 | 738 | 549 | 207 | 192 | 652 | 92 |
| R^2 | 0.40 | 0.46 | 0.40 | 0.44 | 0.40 | 0.43 | 0.41 | 0.30 |
| BP LM test | 15.31 | 0.63 | 0.36 | 3.23 | 6.09 | 2.18 | 9.36 | 3.17 |
| Hausman χ^2 test | 3809.84 | 120.91 | 1196.7 | 352.64 | 318.25 | 122.1 | 970.07 | 179.24 |
| Wald χ^2 test | 1783.71 | 656.35 | 1738.84 | 1242.7 | 326.05 | 415.74 | 1329.71 | 91.67 |

*** significant at 1% level, ** 5% level, * 10% level, # relevant with the t-statistic is at least one. ^a National accounts capital income exclusive of an allowance for labour income of owner operators included in the national accounts aggregate gross operating surplus and mixed income. (Data were not available to complete the adjustment for Property & business services). ^b Firms in the BLS only in 1994-95 and firms with incomplete data not included in the regression. Typically, each firm is observed three times.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

Figure 4.5 Contribution of ICT and ICT with complementary factors to productivity growth^a — basic and augmented models

Percentage points



^a Contribution of each computer use variable and its interaction effects to average labour productivity growth evaluated at the BLS regression sample means.

Source: Regression analysis based on the BLS Confidentialised Unit Record File (CURF). See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

Table 4.3 Estimated impact of ICT and complementary factors on productivity growth — augmented model

Regression coefficients, Dependent variable is change in labour productivity, unweighted panel estimates

| <i>ICT interactions</i> | <i>Manufacturing</i> | <i>Construction</i> | <i>Wholesale trade</i> | <i>Retail trade</i> | <i>Accom., cafes & restaurants</i> | <i>Transport & storage</i> | <i>Property & business services</i> | <i>Cultural & recreational services</i> | <i>Incidence^a of</i> | |
|--|----------------------|---------------------|------------------------|---------------------|--|--------------------------------|---|---|---------------------------------|------------------|
| | <i>Manufacturing</i> | <i>Construction</i> | <i>Wholesale trade</i> | <i>Retail trade</i> | <i>Accom., cafes & restaurants</i> | <i>Transport & storage</i> | <i>Property & business services</i> | <i>Cultural & recreational services</i> | <i>Positives</i> | <i>Negatives</i> |
| Intercept | 1.614*** | 2.395*** | 2.082*** | 1.742*** | 1.655*** | 1.701*** | 1.998*** | 0.392# | 8 | 8 |
| Log(y_{t-1}) | -0.467*** | -0.664*** | -0.553*** | -0.536*** | -0.501*** | -0.500*** | -0.539*** | -0.281*** | | 8 |
| <i>k</i> dot | 0.358*** | 0.223*** | 0.342*** | 0.331*** | 0.265*** | 0.351*** | 0.246*** | 0.204*** | 8 | |
| Size ('00) ^b | -0.076** | 0.037 | 0.021 | -0.368*** | -0.478*** | -0.052 | -0.070# | -0.096 | | 4 |
| ICT_d1 (< 2yrs) | 0.120** | -0.420** | -0.317** | 0.107 | -0.019 | -0.111 | -0.174# | 0.599# | 2 | 3 |
| ICT_d2 (short) | 0.130** | 0.304# | 0.241** | 0.087 | 0.308# | -0.194 | 0.179# | -0.049 | 5 | 0 |
| ICT_d31 (2-5yrs) | 0.025 | 0.046 | 0.066 | 0.099# | 0.120# | -0.043 | -0.070 | -0.012 | 2 | 0 |
| ICT_d4 (> 5yrs) | -0.063* | -0.159# | -0.227*** | -0.085# | -0.072 | 0.013 | -0.327*** | 0.313# | 1 | 5 |
| Netacc | 0.029* | 0.030 | 0.070*** | 0.031 | 0.126# | 0.099# | 0.096** | 0.129 | 5 | |
| <i>ICT and skill</i> | | | | | | | | | | |
| ICT_d1 X wagerate ² | + | + | + | + | + | + | + | + | 7 | |
| ICT_d2 X wagerate ² | + | + | + | + | + | + | + | + | 7 | |
| ICT_d3 X wagerate ² | + | + | + | + | + | + | + | + | 8 | |
| ICT_d4 X wagerate ² | + | + | + | + | + | + | + | + | 8 | |
| <i>ICT and product innovation</i> | | | | | | | | | | |
| ICT_d1*_INNOVAT | | | | | - *** | | | | | 1 |
| ICT_d2*_INNOVAT | | | | - * | + | | | | 1 | 1 |
| ICT_d3*_INNOVAT | | - * | | - # | | | | | 1 | 2 |
| ICT_d4*_INNOVAT | + | + | + | | | | - # | | 2 | 2 |
| ICT_d1*L1INNOVAT | | | | | + | | | | 1 | |
| ICT_d2*L1INNOVAT | | | - * | | | - # | | | | 2 |
| ICT_d3*L1INNOVAT | | | | | - # | | | | | 2 |
| ICT_d4*L1INNOVAT | + | - # | | | | | | | 1 | 1 |

(Continued on next page)

Table 4.3 (continued)

| | Manufacturing | Construction | Wholesale trade | Retail trade | Accom., cafes & restaurants | Transport & storage | Property & business services | Cultural & recreational services | Incidence of positives | Incidence of negatives |
|---------------------------------------|---------------|--------------|-----------------|--------------|-----------------------------|---------------------|------------------------------|----------------------------------|------------------------|------------------------|
| ICT and organisational changes | | | | | | | | | | |
| ICT_d1*_BUSPRAC | - # | | | + # | | | | | 1 | 1 |
| ICT_d2*_BUSPRAC | - ** | | - *** | | | | | - # | 3 | 3 |
| ICT_d3*_BUSPRAC | | | + *** | | - * | + ** | + # | | 1 | 1 |
| ICT_d4*_BUSPRAC | | | | | | | | - # | 1 | 1 |
| ICT_d1*L1BUSPRA | | | + # | - # | | | | | 1 | 1 |
| ICT_d2*L1BUSPRA | + *** | | + ** | | | | | + # | 3 | 3 |
| ICT_d3*L1BUSPRA | + * | | | | | - ** | | + # | 2 | 1 |
| ICT_d4*L1BUSPRA | + *** | + # | + # | | | + # | | + # | 5 | 1 |
| ICT_d1*BUSREBI | - # | | + # | | + # | + * | | | 3 | 1 |
| ICT_d2*BUSREBI | - # | | + # | + ** | + # | | + ** | | 4 | 1 |
| ICT_d3*BUSREBI | | | - # | | | | | | 1 | 1 |
| ICT_d4*BUSREBI | + *** | | | | + # | | + ** | | 3 | 1 |
| ICT_d1*L1BUSRE | + # | | - # | | + ** | | + # | | 3 | 1 |
| ICT_d2*L1BUSRE | | - # | | | + # | | | | 3 | 1 |
| ICT_d3*L1BUSRE | + *** | + ** | | | + # | | | | 3 | 1 |
| ICT_d4*L1BUSRE | | | | | + # | | | | 3 | 1 |

*** significant at 1% level, ** 5% level, * 10% level, # relevant the t-statistic is at least one. a Only coefficients with t-statistic of one or more counted. b Firms in the BLS only in 1994-95 and firms with incomplete data not included in the regression. Typically, each firm is observed three times.

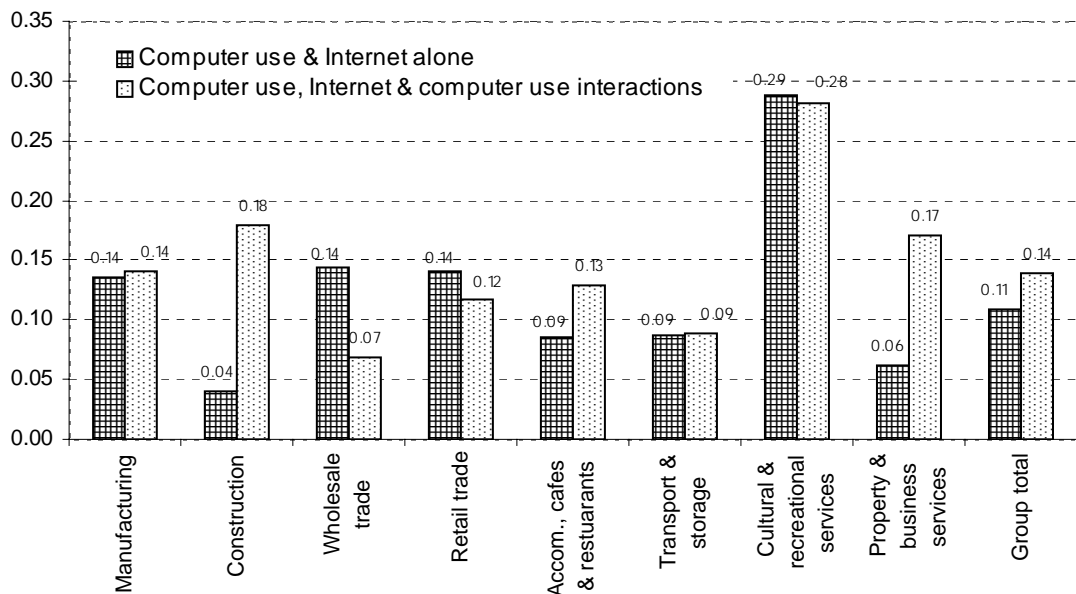
Source: Regression analysis based on BLS unit record data. See ABS (*Business Longitudinal Survey, 1994-95 to 1997-98*, Cat. no. 8141.0.30.001).

4.5 A re-aggregated view

Overall, the current analysis suggests that the use of computers had a positive impact on firms productivity growth during a key mid-1990s period (figure 4.6). Computer use and Internet access alone is estimated to have raised MFP growth for the eight industry sectors (as a group) by over 0.11 percentage points per year over the period 1994-95 to 1997-98. Once the influence of associated skill, restructuring and organisational characteristics of firms is explicitly taken into account, MFP growth is estimated to have been raised by a further 0.03 points to 0.14 percentage points per year.

Noting the dynamic structure of the impact of computer uptake on MFP growth, as computer use becomes established, the incremental growth in MFP would decline (although the level effects would not decline). Growth theory would predict that future MFP growth would be contributed by other technological and organisational changes.

Figure 4.6 **Estimated contribution of ICTs to multifactor productivity growth^{ab}**
Percentage points



^a Contribution of Internet access and computer use alone (hatched bars), and the contribution of Internet access and computer use alone plus computer use interactions (spotted bars) evaluated at the mean of the sample of BLS firms included in the regression analysis. ^b The contributions of the Manufacturing, Construction, Wholesale trade, Retail trade, Accommodation etc, Transport & storage, Property & business services and Cultural & recreational services are weighted by their Australian national accounts valued added share to form the group total reported. These BLS sector activities cover around 52 per cent of GDP. Market sector activities (appendix A) not included in this analysis are Agriculture etc, Mining, Communications services and Finance & insurance. Property and business services is not included in the market sector in traditional productivity analyses (chapter 2).

Source: Estimates based on BLS data; EconData (2002).

4.6 Main findings

Firm-level data for the mid-1990s suggests that businesses using computers had, on average, higher labour productivity than non-users. There was also a tendency for firms that had used computers longer to also have had higher labour productivity, on average. That said, the firm-level data did not indicate the underlying reasons for the productivity differences (eg differences in capital intensity versus efficiency differences) or explain the substantial variability in the level of labour productivity across firms. These considerations suggest that it would be difficult to use sectoral averages and simple comparisons of performance to draw inferences about the influence of computer use on productivity.

In order to link firm performance, as measured by MFP, with use of computers, an empirical model of economic growth was adopted. Simulations based on this model across eight industry sectors suggest that:

- the use of computers had a positive effect on MFP growth in the mid-1990s;
- the MFP effects varied across industries;
- the positive effect was largest in the earlier years of uptake but appears to taper off as firms return to 'normal' growth after the productivity boost of the new technology; and
- the level of human capital or skill base within firms, firms' innovation experience, application of advanced business practices and intensity of organisational restructuring interacted with the uptake of ICTs in boosting MFP growth, while the nature of the complementary relations appeared to vary significantly between sectors.

Overall, the analysis suggests that the uptake of computers was associated with a substantial reorganisation of industry and ways of working and that these developments raised the level of productivity amongst firms. The estimated contribution of these changes to growth over the period 1994-95 to 1997-98 was 0.14 percentage points per year.

The analysis also provides empirical support for the proposition that adoption and spread of a new general purpose technology, such as ICTs, can contribute to economic growth, although the intensity and duration of any individual contribution may vary between technologies and the implications of each technology in different sectors.