The Role of ICT in Australia's Economic Performance: Investigating the assumptions influencing productivity estimates

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Introduction

In early 2004 Australia's National Office of the Information Economy (NOIE) – now part of DCITA – posed two central questions regarding the role of ICT in productivity growth:

- Do the assumptions underlying the index-based productivity measures adequately capture the "Information Revolution" characteristics of ICT? and,
- Can the contribution of ICT to the competitive transformation of the economy be identified from these productivity measures?

3 measurement projects

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Diewert and Lawrence have undertaken 3 projects aimed at responding to these questions:

- Project 1: Used ABS sectoral data to examine whether there is evidence of non–constant returns to scale in Australian industry and whether standard user cost formulae reflect the value of ICT to producers
- Project 2: Constructed new aggregate productivity database with broader coverage than ABS MFP and estimated more detailed econometric model
- Project 3: Examines whether non-ICT capital depreciation rates used by statistical agencies are lower than econometric estimates for 4 countries

Project 1's focus

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- First, we developed a new econometric approach to modeling returns to scale using a multi-equation monopolistic markup model
- Provides a better basis for separately identifying the effects of technical change and returns to scale.
- Second, we allowed for a divergence between the user cost of ICT and the value of ICT in production
- This provides an empirical basis for testing whether the growth accounting method is understating the likely contribution of ICT to economic growth.

The monopolistic markup model

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- A divergence between the user cost of ICT and the value of ICT in production is mathematically equivalent to a monopolistic markup on ICT inputs
- If the markup factor for ICT turns out to be 1, then the usual user cost assumptions are justified and no disequilibrium in the ICT market is found.
- However, a more likely hypothesis is that ICT inputs are worth more than their price. That is, they contribute more to the value of output at the margin than their marginal cost.

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The model (1)

- Assumed one output and two inputs – ICT inputs and all other inputs combined
- period t monopolistic profit maximisation problem:
- (1) $\max_{x} P[f(x, t),t]f(x, t) \square w_1^t x_1 \square w_2^t x_2$
- Obtain following estimating equations:
- (10) $w_1^t/p^t = M_1\, \partial f(x_1^t, x_2^t, t)/\partial x_1 \qquad t = 0,1,\ldots,T;$
- $\qquad w_2^t/p^t = M_2\, \partial f(x_1^t, x_2^t, t)/\partial x_2$.
- If value is greater than period t cost, then the period t markup factor, M_n^t, will be less than one:
- (11) $M_n^t \equiv w_n^t/p^t \partial f(x_1^t, x_2^t, t)/\partial x_n < 1.$

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The model (2)

- Use normalised quadratic production function
- Estimating equations are:
- (17) $y^t/x_1^t = a(1/x_1^t) + b_1 + b_2\,(x_2^t/x_1^t) + c_1 t$
  $+ c_2(x_2^t/x_1^t)t + d(1/x_1^t)t \square (1/2)e^2[v^t]^2$;
- (13) $w_1^t/p^t = M_1[b_1 + c_1 t + (1/2)e^2\,(v^t)^2 \square e^2 \square v^t]$
- (14) $w_2^t/p^t = M_2[b_2 + c_2 t + e^2 v^t]$ $\qquad$ $t = 0,1,\ldots,T.$
- where $v^t \equiv [\square x_1^t \square x_2^t]/x_1^t$ is an exogenous variable
- Incorporate up to 3 spline terms on technology and markups
- Set initial markups equal to each other

The database used

- Used modified and supplemented ABS sectoral productivity database covering 24 years 1980-2003
- Looked at 12 sectors using gross value added, labour hours and 10-12 capital components
- ICT is computers, software and electronic equipment
- ABS uses two stage process for inputs – largely exogenous RoRs in first stage to form capital aggregate as many of the balancing RoRs are low and/or negative
- We use 4 per cent real ex-ante RoR in one stage process
- Several of our sectoral productivity trends are lower than those of ABS/PC
- Only 4 of the 12 sectors appear to have robust data

The problem industries

	Outputs/ Inputs	Balancing Real RoR	Labour share
Accommodation, cafes etc	85%	0.42%	77%
Agriculture, forestry & fishing	46%	1.84%	33%
Communication	88%	1.47%	57%
Construction	107%	8.92%	77%
Cultural & recreational	115%	12.03%	58%
Electricity, gas & water	69%	0.27%	37%
Finance & insurance	85%	0.70%	60%
Manufacturing	101%	4.20%	63%
Mining	125%	10.65%	28%
Retail trade	88%	-0.34%	82%
Transport & storage	80%	-0.70%	66%
Wholesale trade	97%	3.34%	70%

Econometric results

Industry	Returns to Scale	Technical Change	Non-ICT Markup Factor	ICT Markup Factor
Manufacturing	0.8835	0.0138	1.1655	0.8227
Wholesale	1.0736	-0.0169	1.0411	0.6641
Retail	0.8924	-0.0070	1.4503	0.6982
Construction	1.2719	-0.0059	0.7600	0.4975

Project 1 conclusions

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- Varying evidence found with respect to returns to scale
- However, consistent evidence found across all industries examined that ICT contributes more to output than its cost to producers.
- Standard growth accounting productivity measures will not adequately capture the "Information Revolution" characteristics of ICT
- Greater attention to the uptake of ICT may have an important role in improving economic growth
- A major emphasis going forward has to be on improving the quality of available data and making sure that it better reflects changes in quality in the services sectors
- Significant problems with the internal RoRs found

Project 2 focus

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- Sought to address a number of the key problems identified with the National Accounts based productivity data in Project 1
- Construction of a new productivity database for Australia with broader coverage and better microeconomic foundations
- We then undertake econometric modelling using this database and a more detailed model than that developed in our initial study.

D-L compared to ABS productivity databases

- broader coverage of the economy – D–L include 16 of the 17 major industrial sectors whereas the ABS ‘market sector’ only covers 12 of the 17 sectors. D-L exclude Government administration and defence whereas the ABS also excludes Health, Education, Business and property services and Personal services. With the changing composition of the economy, the private sector now accounts for significant proportions of Health, Education and Personal services output and nearly all of the relatively large Business and property services sector’s output.

D-L compared to ABS productivity databases

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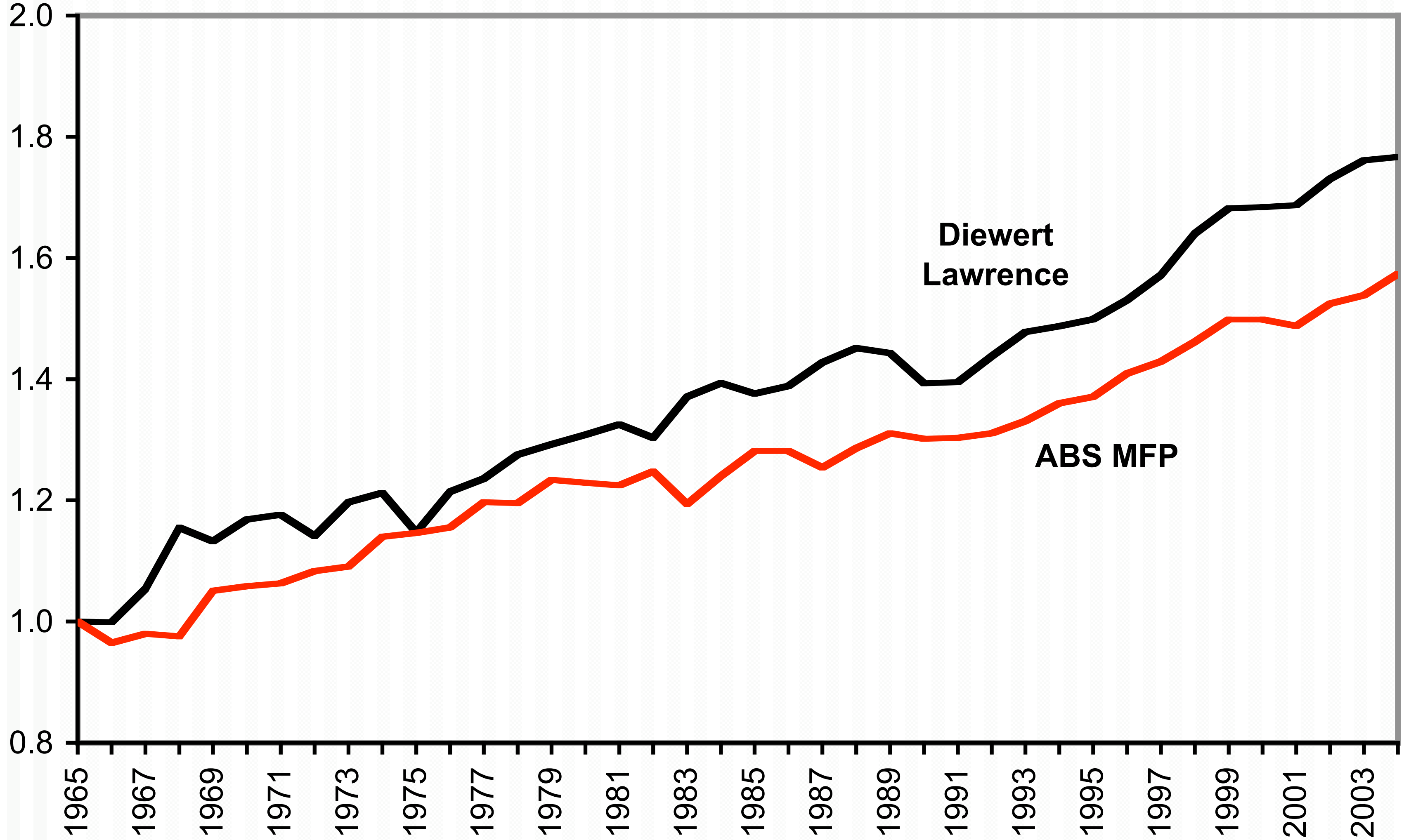
- Builds up output measure from final demand components rather than sectoral value added – this allows a more accurate output measure to be used as interindustry flows of intermediates are netted out and more accurate records are available for end consumption components.
- Both outputs and inputs expressed in terms of conceptually appropriate producer prices.
- Constructs consistent capital and inventory input series using Jorgenson geometric depreciation approach and smooths the depreciation rates used by the ABS.

Results - TFP


2.0
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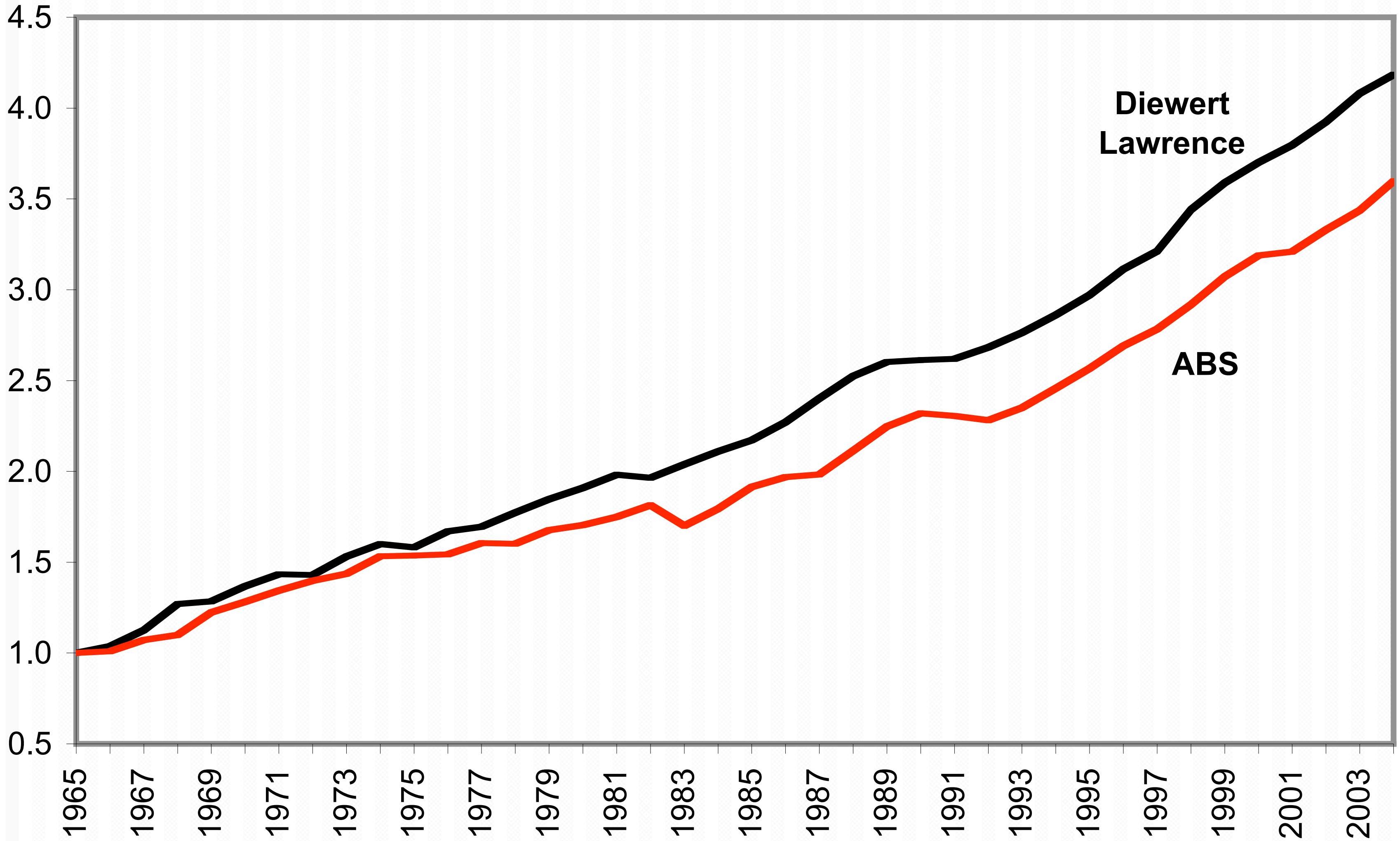
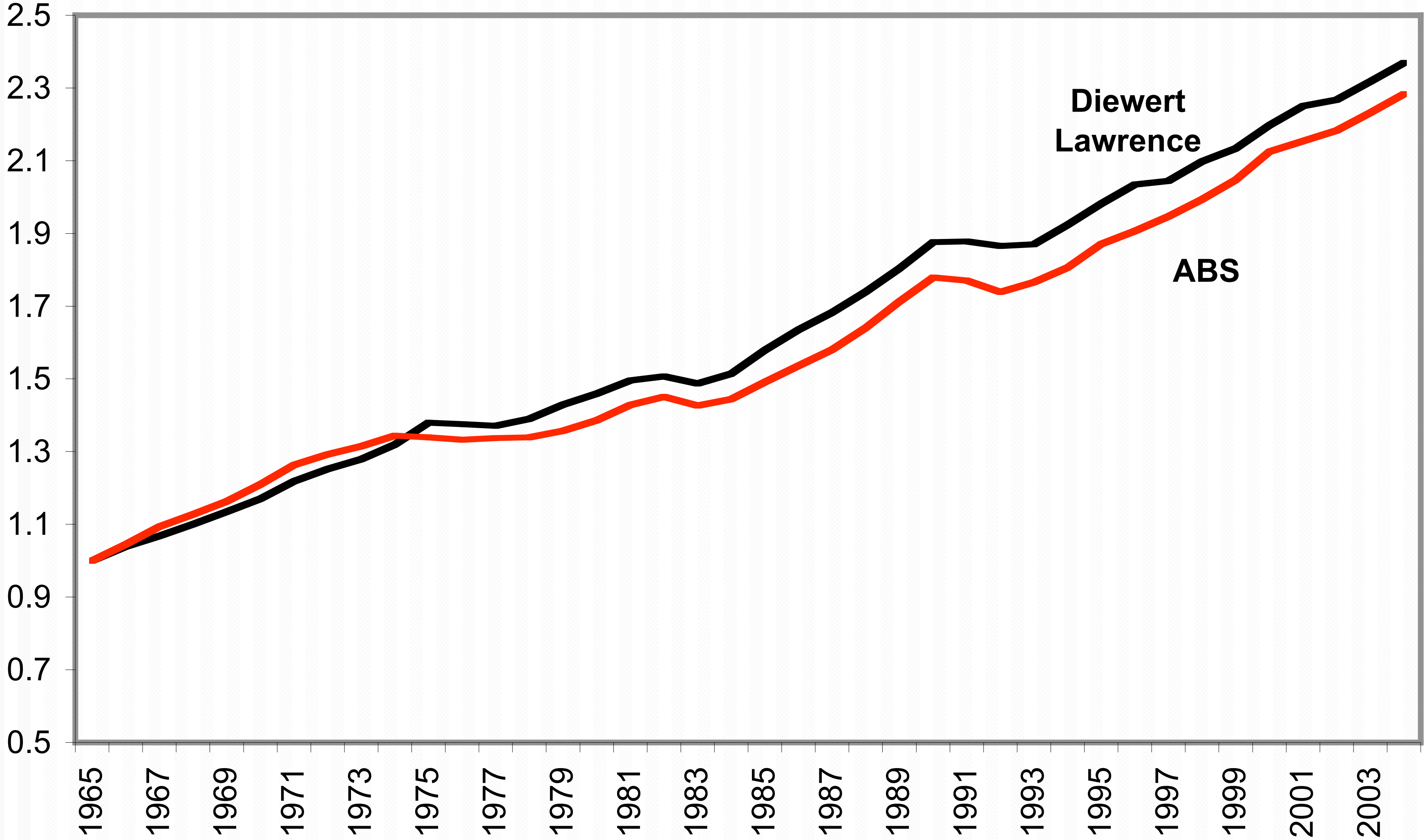
Diewert
Lawrence
ABS MFP

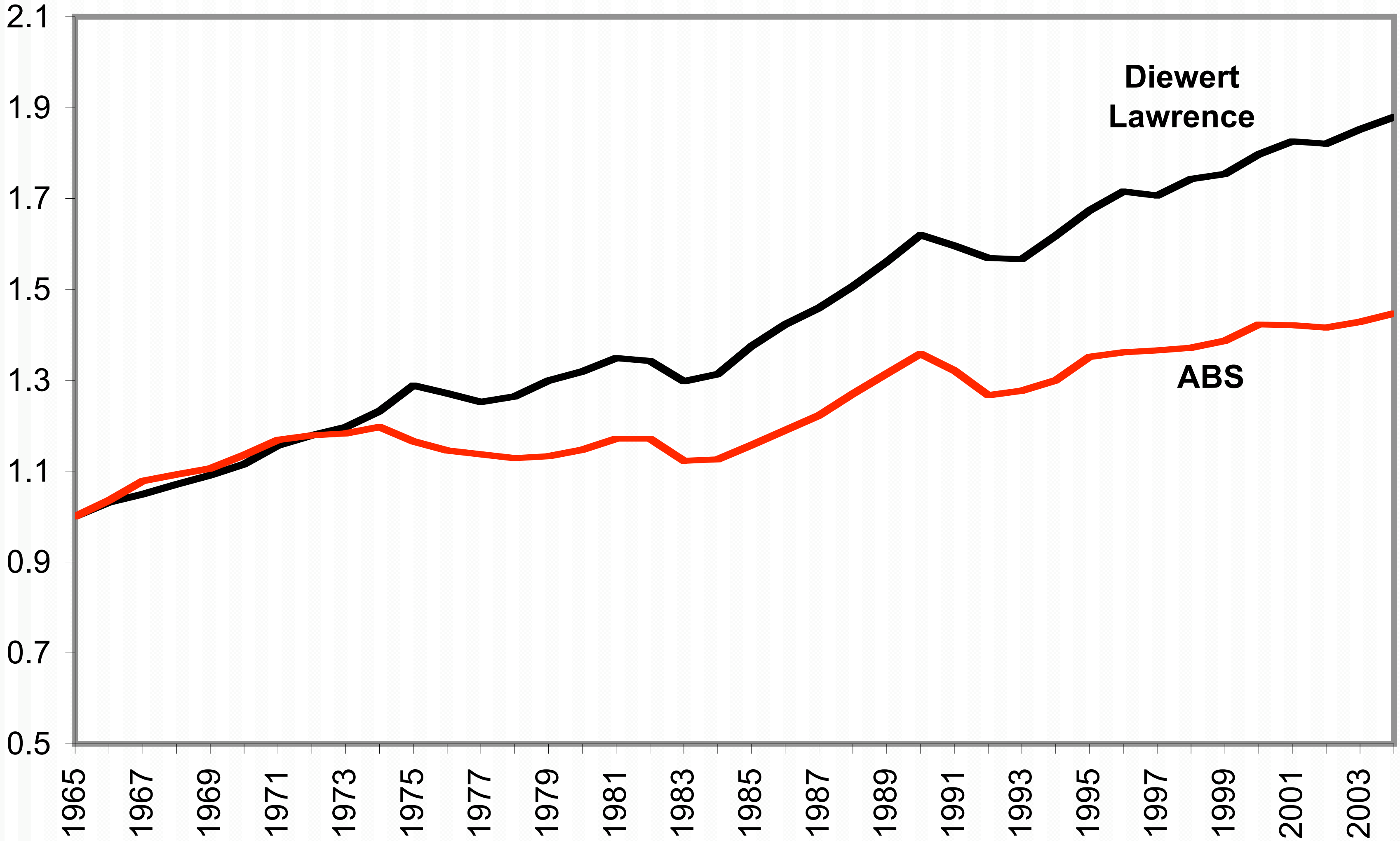
Results - Output



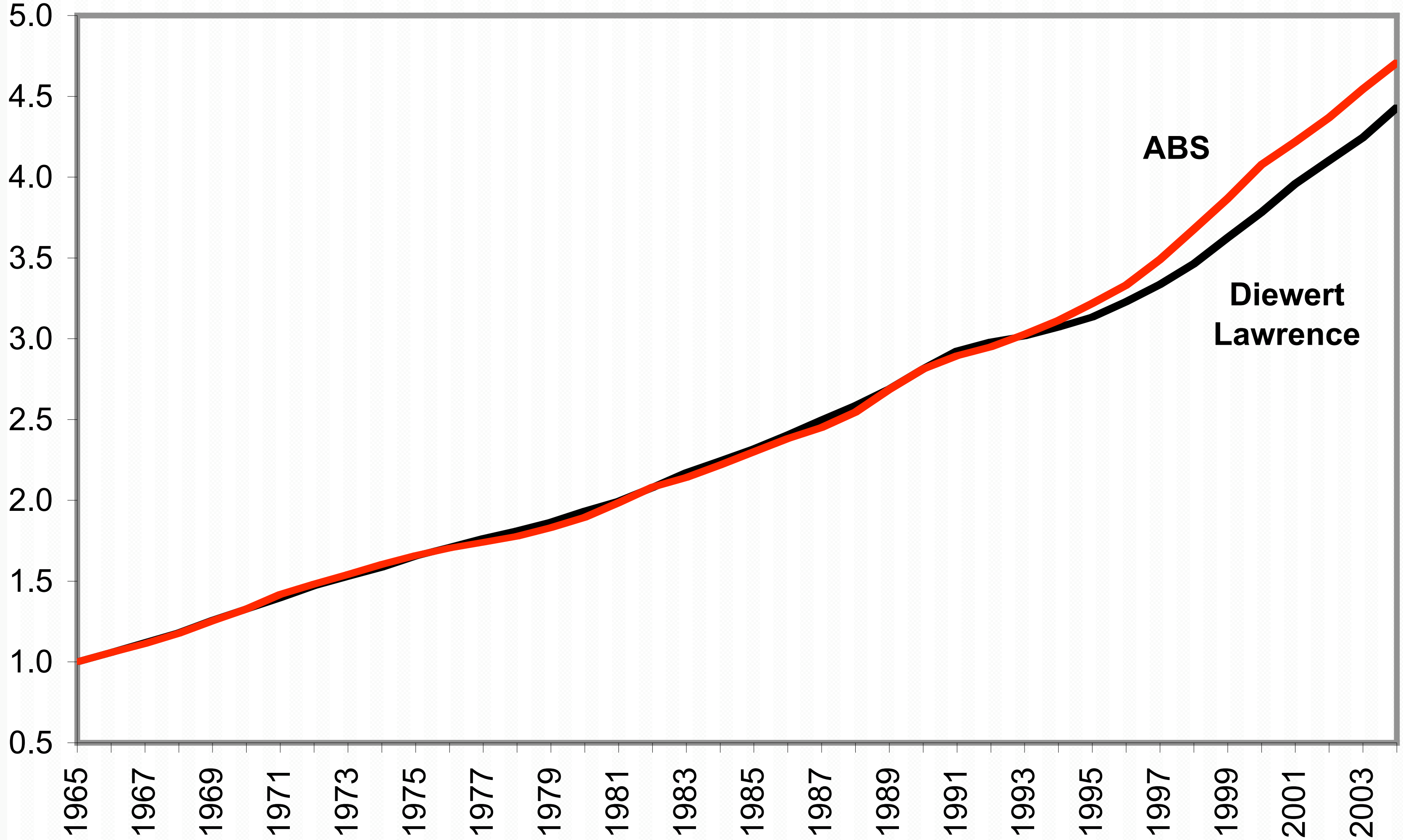
Results - Inputs



Results - Labour



Results - Capital



Production function estimation

- Production function has one output aggregate and four inputs
- Output aggregate is Fisher chain of C, G, components of I, and X
- Inputs include:
- ➢ Labor
- ➢ ICT capital services
- ➢ Non-ICT capital services
    - ➢ Imports

Production function estimation

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- Estimate production function and four first order conditions (one for each input):
- (15) $y^t = b + c^T x^t + t d^T x^t + et \ \square \ (1/2)\ x^{tT} S x^t / \square^T x^t$
- (7) $w_i^t / p^t = M\ \partial f(x^t, t) / \partial x_i$ for $i = 1, 2, 3$
- (8) $w_4^t / p^t = M \square \partial f(x_1^t, x_2^t, x_3^t, x_4^t, t) / \partial x_4$ for ICT input
- Interpretation of coefficients:
  - b = returns to scale
  - c = marginal productivity parameters
  - d = change in marg prod params (linear spline)
  - e = technical change (linear spline)
  - S = substitution matrix (allowed to trend)
  - M = markup
  - _ = ICT relative efficiency.

Key results

- TFP growth in the expanded market sector has been quite high with a high average annual TFP growth over the 12 years to 1972 of around 1.66 per cent, more modest average growth of 1.22 per cent over the period 1972–95 and then very high average TFP growth of 1.85 per cent over the last decade
- compares with ABS multifactor productivity average annual changes of 1.19 per cent per annum for the 7 years to 1972, 1.05 per cent for the period 1972–95 and 1.55 per cent per annum for the last decade
- demonstrates the importance of including the additional service sectors included in the D–L database

Key results

- Modest increasing returns to scale (1.07 on average)
- Most TFP growth accounted for by technical change
- Monopolistic markup of 8 percent
- ICT relative efficiency parameter implies that ICT is undervalued. Marginal unit that costs $1 would generate roughly $1.42 worth of output.
- 3 Possible reasons for undervaluation:
  - Rapid price declines leave market in ongoing state of disequilibrium
  - Innovation related externalities associated with investment in ICT
  - Intangible investments associated with ICT

Project 3 focus

- There appears to be a problem with the depreciation rates used by statistical agencies in forming capital stocks and measures of the user cost of capital
- Official depreciation rates for most types of capital (other than computers and software) are lower than those indicated by preliminary econometric estimation
- If confirmed, this result has major significance for productivity measurement worldwide
- project addresses how depreciation rates for the components of reproducible capital can be *scientifically* determined as opposed to the usual practice in most countries where depreciation rates are simply *assumed* by statistical agencies.

Importance of depreciation

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- **If the assumed depreciation rates are too low, then capital input (in levels) will be too high and in a growing economy, capital input growth will be overstated. This will lead to TFP growth estimates that are too low.**
- **to gain a full understanding of the role of ICT in productivity growth we need to be confident that all types of capital are measured accurately, not just computers and software. This has important implications for the identified take–up rate of ICT in other forms of capital.**
- **to develop tax policies that are consistent with the economy being able to achieve productive efficiency, it is necessary that policy makers have reasonably accurate measures of economic depreciation**

Methodological approach

- We represent the technology of the market sector by either a production function (where reproducible capital stock components appear as inputs) or a dual variable profit function with the capital stock components appearing as exogenous variables
- Capital stock components can be represented as a weighted sum of past investments in the corresponding components, where the weights depend on an unknown depreciation rate for each capital stock component
- These unknown rates can then be estimated in the context of a traditional econometric production model.

Methodological approach

- initial approach was based on the estimation of a variable profit function for Australia's market sector
- it would be useful to see if a similar result can be obtained using a primal production function approach.
- initial results obtained using a production model that had estimating equations for: (1) aggregate output less inventory and land services, (2) exports, (3) imports and (4) labour
- initial results aggregated all reproducible capital into a single capital aggregate. It is necessary to extend our methodology to estimate depreciation rates for more disaggregated components of the reproducible capital stock

Countries covered

- The analysis will cover specially constructed databases for 4 countries:
  - Australia
  - Canada
  - Japan
  - United States
- Work to date on assembling the databases has revealed a number of anomalies and inconsistencies in published National Accounts sources

Conclusion

- Since productivity growth is the most important factor in improving living standards, it is important to be able to measure productivity growth accurately as a first step in attempting to determine the factors that cause productivity growth rates to vary.
- The work reported here is part of ongoing research aimed at improving productivity measurement. By its very nature it is work-in-progress and part of an ongoing process.
- The ABS has made a valuable contribution to this work by providing advice and access to data and interaction with the Productivity Commission has been appreciated
- We thank DCITA for their support and interest in this work