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THE SLOWDOWN IN AUSTRALIAN PRODUCTIVITY GROWTH: SOME AGGREGATED AND DISAGGREGATED EVIDENCE

by

A. Phipps, J. Sheen and C. Wilkins

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ABSTRACT

The decline in Australian aggregate labour productivity growth in the 1980's was closely associated with a fall in capital intensity. While many believe that real wage restraint was the explanation for these aggregate outcomes, this paper examines the data disaggregated to an industry level to see whether industrial composition changes can refute the factor substitution argument.

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I Introduction

As can be seen from Table 1, Australian labour productivity growth in the 1980s was unusually slow compared to that of the 1960's or even the 1970s. A similar phenomenon was observed in many countries and, consequently, a number of different possible reasons for this have been suggested.[1] In Australia, one explanation seems to have become widely, if not universally, accepted. This argument, which can be termed the 'factor substitution' argument, asserts that the decline in labour productivity growth is largely a reflection of real wage restraint, the impact of which on relative factor prices has caused substitution of labour for capital, lowering the capital to labour ratio and therefore labour productivity growth, while underlying total factor productivity growth has remained unchanged. This argument appears to have become the accepted wisdom amongst major Australian economic policy makers (for example, see Department of the Treasury (1990), p35) and has also become entrenched in Australian economic modelling and forecasting (for example, see Dowrick (1990), Murphy (1988), Upcher and Taplin (1990)).

TABLE 1

Average Rates of Growth
Labour Productivity and Capital Intensity
(% per quarter)

Period	Y/L	K	L	K/L
1959(4)-1969(4)	0.64	1.42	0.66	0.76
1970(1)-1979(4)	0.46	1.03	0.39	0.64
1980(1)-1990(4)	0.21	0.89	0.51	0.38

Y= real gross domestic product
L = total employment
K = capital stock

In this paper we examine a critical link in the above argument, this being the relationship between movements in the capital to labour ratio and changes in labour productivity in Australia. There are two parts to this examination. In the first section of this paper we follow tradition in examining the statistical evidence for this conventional argument using economy wide aggregate data. Rather than standard regression techniques, however, a cointegration approach is used so as to correctly examine the relationship between the series in question which are clearly non-stationary.

The second section of the paper, on the other hand, looks at the problem in rather a different way. In particular, data disaggregated to an industry level is used to examine the extent to which movements in aggregate labour productivity have been affected by changes in the industry composition of the economy. A similar analysis is also carried out with respect to the aggregate capital to labour ratio. These more detailed results provide an interesting contrast to some of the conclusions suggested by the first section of the paper.

The paper concludes with some remarks on how our analysis reflects on the conventional view and also provides some comments on how this may affect economic policy considerations.

II An Aggregate Model of Labour Productivity

In our modelling of aggregate labour productivity, we use quarterly data from 1959(3) to 1990(4). The data, apart from those for the capital stock, were taken from the Treasury NIF database. Gross domestic product at constant prices, seasonally adjusted, was used for output (Y), while total employment, seasonally adjusted, was used to approximate labour inputs (L). The capital stock series (K) is the sum of plant and equipment and non-dwelling construction for public and private enterprises. Annual data is from ABS 5221.0. Quarterly data has been interpolated using national accounts investment series.

From inspection, it was immediately obvious to us that all of our series are non-stationary. Non-stationarity is a serious problem because its existence invalidates the basis of classical hypothesis testing. A massive literature has emerged in the last fifteen years on methods to test for and to cope with the existence of non-stationarities. Using univariate methods (in particular, those advocated by Phillips and Perron(1990) which use non-parametric methods to test the null of non-stationarity), we have established that we are unable to reject the null of non-stationarity of output, labour, capital, labour productivity and capital intensity and that they are all probably I(1) processes - that is they can be made stationary by first differencing[2].

[1] For example, see Baily(1981,1982), Baily and Schultze(1990), Turnovsky, Folie and Ulph(1982), Romer (1990), Griliches(1988), Olson(1988).

[2] These results are available from the authors..

Consequently, if there is to be a long run (log-)linear relationship between their levels, these I(1) processes would have to cointegrate to form one or more stationary or I(0) processes.

Now, if these variables do not cointegrate, this may be because there are additional unspecified variables that are a necessary part of the relationship between the included variables. Ideally, one should aim to measure these omitted variables and test for cointegration once these omitted variables have been added to the existing set. However, in reality, this may be difficult or simply not possible. An alternative is to proxy these omitted variables by the inclusion of trend variables. The introduction of time trends to obtain a cointegrating relationship is an explicit admission of ignorance. Furthermore, there are obvious difficulties with the methodology of adding time trends to the model until cointegration is achieved. Nevertheless, the use of trends in production theory is widespread as a means of incorporating technological progress which is difficult to observe directly. In this section we shall utilise conventional production function theory and proxy technological progress using deterministic trends.

Let us consider a standard production function:

$$Y(t) = f(A(t),\ Ku(t).K(t),\ Lu(t).L(t)) \tag{1}$$

where Y, K and L have their usual meanings, Ku is the capacity utilisation rate, Lu is the labour utilisation rate and A(t) represents the state of technology or knowledge and may be given a deterministic or stochastic representation. Using a deterministic representation, we assume a Cobb-Douglas function with disembodied technological progress:[3]

$$Y(t) = A\, e^{\lambda t}\, (K(t)Ku(t))^{\alpha}\, (L(t)Lu(t))^{\beta} \tag{2}$$

$Ae^{\lambda t}$ captures so-called total factor productivity (TFP). This equation may be written in log-linear form, after subtracting $\ln L(t)$ from both sides, as

$$\ln(Y/L)(t) = a + \lambda t + \alpha \ln K(t) + (\beta-1)\ln L(t) + \alpha \ln Ku(t) + \beta \ln Lu(t) \tag{3}$$

If there are constant returns to scale, $\beta-1 = -\alpha$ and (3) reduces to

$$\ln(Y/L)(t) = a + \lambda t + \alpha \ln(K/L)(t) + \alpha \ln Ku(t) + \beta \ln Lu(t) \tag{4}$$

[3] This is consistent with Whiteman's (1991) finding that technical progess in Australian manufacturing has been labour-augmenting. In the Cobb-Douglas, neutral, labour-augmenting and capital-augmenting technical progess reduce to similar functions of time.

Some justification for using the much-criticised Cobb-Douglas function apart from the obvious appeal of its simplicity is required. The two most frequently cited criticisms of this formulation of the technology are that factor shares have not been constant and that estimates of the elasticity of substitution obtained from labour demand functions suggest a value closer to a half than unity.[4] However, both of these criticisms are based on the assumption of profit maximisation under competitive conditions with zero adjustment costs so that factors are always paid their marginal products. There is some doubt whether this is really the case, a doubt reinforced by our results of Section III.[5]

We have not found suitable series for capacity or labour utilisation[6]. As a consequence, the cyclical variation of labour productivity, resulting from the quasi-fixity of labour inputs and labour hoarding, which itself may result from investment in firm-specific training, other hiring or firing costs or imperfect information/signal extraction problems, should show up in the short run dynamics of our output and employment equations. This means that in the short run we would not expect our data to support a static technical relationship between output, employment and capital. However we might expect that there is a stationary long run relationship underlying the short run dynamics that capture transient capacity and labour utilisation.

One of the key features of labour productivity over the sample is its apparent concavity, reflecting the slowdown. Capital intensity displays this as well, but it is far less smooth with a definite flattening out after 1983. As a consequence, the term A(t) is going to have to make a bridge between the two in the estimated long run relationship. The rate of growth of TFP (neutral technical progress) was approximated initially by a linear time trend (t). To test whether or not there were discrete breaks in TFP growth associated with the oil price shocks of 1973 and the

[4] See, for example, Russell and Tease (1990) and Phipps (1981).

[5] Nevertheless, to stall criticism, in pre-testing, we estimated using OLS two less restrictive production functions which nest the Cobb-Douglas, namely, an approximation to a CES function based on a Taylor's series expansion and a Translog function. In both cases, standard tests indicated that persevering with the simpler Cobb-Douglas function was warranted. In the former, the coefficient on the $(\ln K-\ln L)^2$ term of the CES function was not significantly different from zero at the five per cent level. In the second, a variable deletion test indicated that the coefficients on the deleted square and cross-product terms of the Translog were jointly just significant. However, the gains in terms of an improved R^2 and reduced standard error of estimate were so miniscule that persevering with the simpler Cobb-Douglas form seemed appropriate. Hall(1985) and Domovitz et al(1988) have shown that US labour markets are imperfectly competitive by finding a positive correlation between the Solow residual and output. We would not be surprised if this is borne out by Australian data as well.

[6] The overtime hours series available in the NIF database is unsatisfactory after 1984 since it appears to contain serious rounding errors. The published ABS series in DX only begins in 1980. Average hours are available from NIF, but again, there are a number of very peculiar spikes which have excessive leverage in estimation. Lastly, the CAI-Westpac capacity utilistion series applies to manufcturing only which need not be representative of the rest of the economy.

introduction of the Accord in 1983, additional time trends (t_{74}, starting at unity in 1974(1), and t_{84}, starting in 1984(1)) were introduced as regressors[7].

A three equation simultaneous system in output, labour, capital and trends was estimated using the Johansen and Juselius(1989) approach to cointegration of non-stationary processes. This involves a basic vector autoregression (VAR) model of the non-stationary levels of the endogenous variables, possibly including weakly exogenous and predetermined variables. The VAR system in the levels of the non-stationary variables can be represented by a VAR in differences with a set of possible cointegrating linear combinations of the non-stationary lagged levels affecting the differences. The multiple cointegrating vectors can be thought of as a description of stationary long run relationships between the variables, which drive the short run dynamics as error-correction mechanisms. Each long run relationship may generate error correction dynamics in any of the equations of the simultaneous system. Johansen and Juselius(1990) show how the cointegrating vectors, the error correction parameters and the parameters of lagged differences of endogenous, exogenous and predetermined variables can be estimated using full information maximum likelihood. Tests for the existence of any number of cointegrating (eigen)vectors are based upon the number of significant associated eigenvalues with the appropriate tables for inference given in their paper. When the cointegrating relationship includes a time trend, the appropriate tables can be found in Johansen(1991). When one has found a system that has acceptable statistical properties, restrictions on the cointegrating vectors and the error correction parameters can be tested using standard likelihood ratio tests. Restrictions may be applied to all or some of the cointegrating vectors. For example, we shall have reason to apply constant returns to scale to only one of our two cointegrating vectors.

An important aspect of this approach is the fact that it seeks to estimate a model involving stationary variables and/or a cointegrating vector of non-stationary ones. The residuals of the cointegrating relationships can be examined to see whether there are any obvious departures from stationarity. Further restrictions to the cointegrating relationships can be applied so that only a single variable enters, enabling a test of the null of the stationarity of that series.

[7] As an alternative to discrete breaks in TFP growth, a smooth reduction in technical progress, reflecting perhaps diminishing returns to R and D or to learning by doing, was modelled by using t^2 in conjunction with t Such a formulation would also be consistent with Mancur Olson's (1988) view that a country's institutions tend to ossify after a prolonged period of stability and that increasingly more effort in 'aging' countries is devoted to struggles over income distribution rather than to efficiency. Another alternative to reflect a general slowing of the rate of TFP growth and more specifically to reflect a reduction in the productivity payoff to capital, tlnK, was tried. We also tried a particular formulation of 'learning by doing' that involved accumulating Y across the sample. This series has a concave shape with little variance and behaves in a very similar way to $-t^2$. We do not report these results because they added no more to those discussed in the text.

Table 2 : ML Estimation (1959:3-1990:4)

	Const	Y/L (t-1)	L (t-1)	K (t-1)	t	t_{74}	t_{84}	ΔY/L (t-1)	ΔY/L (t-2)	ΔY/L (t-3)	ΔL (t-1)	ΔL (t-2)	ΔL (t-3)	ΔK (t-1)	ΔK (t-2)	ΔK (t-3)	$B\text{-}P_{76}$	$Arch_4$	$Norm_4$	R^2
ΔY/L(t)	-.002	-.51	-.42	.38	.077	-.113	.101	.07	.05	.15	.41	.16	.08	1.25	.51	-1.6	22.7	3.1	1.26	.28
	(1.0)	(5.79)	(3.65	(3.9)	(1.48)	(5.65)	(2.2)	(.6)	(.5)	(1.6)	(1.9)	(.7)	(0.4)	(1.2)	(.5)	(1.6)				
ΔL(t)	-.195	.05	-.21	.16	-.12	.011	.101	.03	-.05	-.01	.38	.07	-.002	1.1	.16	-.99	22.3	2.50	.14	.45
	(5.6)	(1.3)	(4.2)	(3.9)	(2.0)	(1.2)	(5.1)	(0.6)	(1.1)	(0.2)	(4.1)	(0.7)	(0.0)	(2.5)	(0.3)	(2.3)				
ΔK(t)	.007	-.005	.005	-.004	.005	-.001	-.003	.03	.003	.009	.05	-.05	.06	.69	.39	-.14	30.1	5.9	6.9	.89
	(0.9)	(0.6)	(.4)	(.4)	(1.00)	(.5)	(0.6)	(2.7)	(0.3)	(1.0)	(2.1)	(1.9)	(2.4)	(6.8)	(3.5)	(1.4)				

NUMBER OF EIGENVALUES

Eigenvalues	0.28	0.20	0.12
λ maximum	39.5	27.00	15.1
	{30.38}	{13.66}	{16.42}
Trace test	81.6	42.1	15.1
	{48.99}	{30.55}	{16.42}

Hence 3 but not 2 eigenvalues can be rejected at 1% level (critical values from Johansen(1991) shown in {..})

THE ASSOCIATED COINTEGRATING RELATIONSHIPS (NORMALISED EIGENVECTORS)
SUBJECT TO 2 RESTRICTIONS IN ONE OF THEM I.E. CONSTANT RETURNS TO SCALE & t_{84} EXCLUSION

1) 1.Y/L(t-1) +.386 L(t-1) -.386 K(t-1) - .004 t + .002 t_{74} -.34
2) 1.Y/L(t-1) - 5.5 L(t-1) + 4.3 K(t-1) - .03 t + .002 t_{74} +.03 t_{84} -5.0

Test of these 2 restrictions: $\chi^2(1) = .02$; MSL= .88. Therefore we cannot reject these restrictions.

ASSOCIATED ERROR CORRECTION PARAMETERS FOR EACH COINTEGRATING RELATIONSHIP

	1.	2.
ΔY/L(t) equation	-.548	.038
ΔL(t) equation	.012	.038
ΔK(t) equation	-.003	-.001

TESTS OF STATIONARITY

	1.	2.
Y/L(t)	37.6	25.6
L(t)	36.8	24.9
K(t)	36.9	25.0

This likelihood ratio test is distributed as χ^2(6 and 5 respectively) with 5% critical values of 12.6 and 11.1. Hence we can reject stationarity for the level of each series.

Our results using this approach are given in Table 2 and Chart 1. The three endogenous variables are labour productivity, labour and capital. This choice permits an easy test of constant returns to scale whereby the coefficients on the levels of labour and capital have to be equal and opposite in sign.

The first key result shown at the bottom of Table 2 is that tests for the null of stationarity of the three main series indicate positive rejection. Second we are unable to reject (at 1%) 2 cointegrating vectors[8] when we include a constant and three deterministic trends, t, t_{74}, and t_{84}. This conclusion is supported by both the maximum eigenvalue test and the trace test described by Johansen and Juselius(1990). Care must be taken when finding more than one cointegrating vector, because any linear combination of them will also cointegrate. In this event it is especially important to test different structural hypotheses. We have tested constant returns to scale and exclusions of various sets of variables.

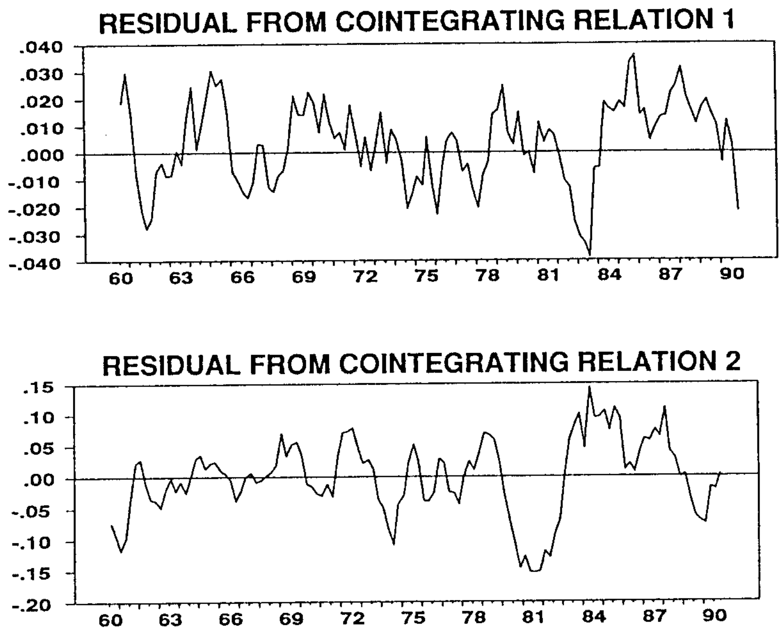
We have been able to reject zero restrictions on capital, labour, t and t_{74}, both jointly and severally. We also reject a zero restriction on t_{84} if applied to both cointegrating vectors. Furthermore we can reject the constant returns to scale restriction on one or both if t_{84} is excluded from both[9]. However the joint restriction of constant returns to scale and a zero on t_{84} in only one vector cannot be rejected (with a marginal significance level of .88).

Thus our third result is presented as the two cointegrating vectors in Table 2 based on a normalisation on labour productivity. The first one would appear to reflect the supply-side of the economy in the form of a long run Cobb-Douglas production function with a labour elasticity of 0.614 and a capital elasticity of 0.386. Total factor productivity growth from 1960 to 1974 is at a rate of 0.4% per quarter, and halves thereafter. A graph of the residual of this relationship is shown in the top diagram in Chart 1D. This may be considered to be a reflection of the business cycle. The fact that t_{84} could be rejected in this CRS production function, suggests that the 1984 Accords might not have had any influence on TFP growth in the Australian economy.

[8] We choose to impose a 1% significance level because we have included 3 different trends in the model. Johansen(1991) provides significance tables based on a single trend, and so we choose to err on the side of caution.

[9] Note that imposing constant returns to scale in one vector alone is not a restriction because of the fact that a linear combination of cointegrating vectors will cointegrate.

Chart 1



The second cointegrating vector is more problematical to explain theoretically. It may come from a demand-side relationship in the long run. It may reflect relative factor shares. However, the exclusion of fundamental macroeconomic variables from our system prevents us from making any real sense of this vector.

The fourth result is that, given these unrejectable restrictions, the errors from the two vectors can appear as error-correction effects in the dynamic equations. Transient errors from the first vector have the most effect on the productivity change (-0.548), a small effect on labour change (.012) and an insignificant effect on capital. The signs are appropriate for supporting a stable longrun equilibrium. The second vector has much smaller effect on the first two equations (though the variance of these errors are somewhat bigger) and the parameter in the productivity equation is positively signed (.038), thus not contributing to stability.

Finally we can see from the top section in Table 2, the results for the FIML estimates of the short run dynamic model for our three variables. The residuals of all three reject the presence of serial correlation, autoregressive conditional heteroscedasticity (ARCH) and non-normality (using the Jarque-Bera test). The 'R^2' for each equation is respectable.

The estimates of parameters are based on the above restrictions. We note that lagged labour change has a significant and large positive effect on productivity change, labour change, and capital change. However lagged productivity change has a significant positive effect on net investment alone. This may be interpreted as evidence of a short run accelerator effect. As expected, lagged capital change affects its current value, but interestingly seems to have transient effects on labour change.

The estimated correlation between the residuals of productivity change and labour change is negative (-.122) reflecting a positive correlation between output and labour change. Capital change residuals are positively correlated to both productivity change (0.36) and labour change (0.23).

The results of this section confirm the widely held view that at an aggregate level the slower rate of productivity growth in the 1980s appears to be largely attributable to the slow rate of growth of the capital to labour ratio over the same period. While it is true that the detection of a significant statistical relationship amongst aggregate macroeconomic time series is interesting and may be of some value for policy making, it is important to investigate the causes of the movements in those aggregates. One possibility is to study the behaviour of the components making up the aggregates. Accordingly, in the next section disaggregated data is used to examine whether the movements in both the ratios may be attributable to changes in the industry composition of the economy.

III Examining Changes in Industry Composition

In this section, we decompose quarterly changes in aggregate labour productivity over the period September 1976 to December 1990 into those due to productivity changes within each industry, and those due to movements of labour between industries. The same method will also be applied to movements in the aggregate capital to labour ratio over this period so as to examine the link between movements in the two ratios.

III.i The Method of Decomposition of Movements in Aggregate Ratios

The first point that must be made in this context is that there are actually two separate effects on aggregate labour productivity of a movement of labour between industries. On the one hand, there is the effect caused by movements of labour between industries with different productivity *levels*. On the other hand, there is the effect caused by movements of labour between industries with different rates of productivity *growth*[10]. These two effects will not necessarily act in the same direction.

A simple example may clarify this. Consider an economy in which there are only two industries, industry A and industry B, and at a particular moment in time, workers in industry A have a high level of labour productivity and workers in industry B have a low level of labour productivity. Now, consider a time period during which two things happen. Firstly, there is a technological innovation in industry B which increases labour productivity in that industry. Secondly, there is a shift of a number of workers from industry A to industry B.

It should be clear that there will be two effects on aggregate labour productivity of this movement of workers between industries. Firstly, there will be a *fall* in aggregate labour productivity caused by the decrease in labour productivity of the workers who moved from the industry with the higher labour productivity level, industry A, to the industry with the lower labour productivity level, industry B. Secondly, there will be a *rise* in aggregate labour productivity caused by the higher rate of growth of labour productivity experienced by the workers who moved from industry A, which experienced no productivity growth, to industry B, which experienced productivity growth. The net impact on aggregate labour productivity of the two effects will depend on the particular levels and changes involved. This simple example provides the intuition behind the more complicated case of the decomposition of changes in labour productivity in a many industry economy. In such a case, the aggregate productivity measure can be considered as a weighted average of the productivity levels in each industry with the weights given by the share

10 This second effect results from the discrete time nature of the analysis. In continuous time:

$$\frac{d}{dt}(X.Y) = X.\frac{dY}{dt} + Y.\frac{dX}{dt}$$

In discrete time, however :

$$\Delta(X.Y) = X_{t-1}.\Delta Y + Y_{t-1}.\Delta X + \Delta X.\Delta Y$$

The third term represents the second effect mentioned in the text.

Chart 3A: Decomposition of Productivity Growth: All Industries

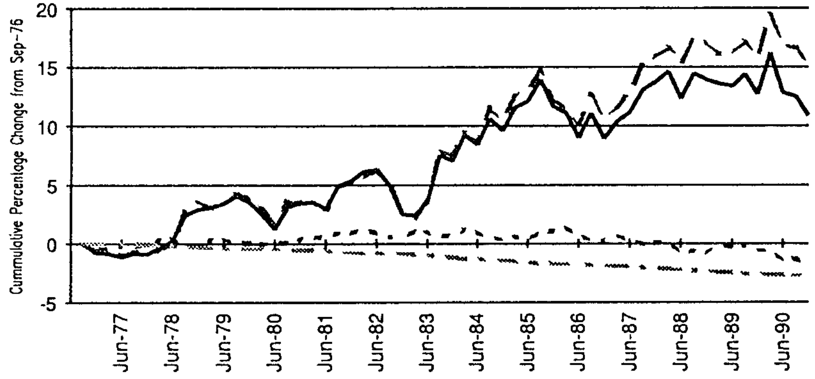
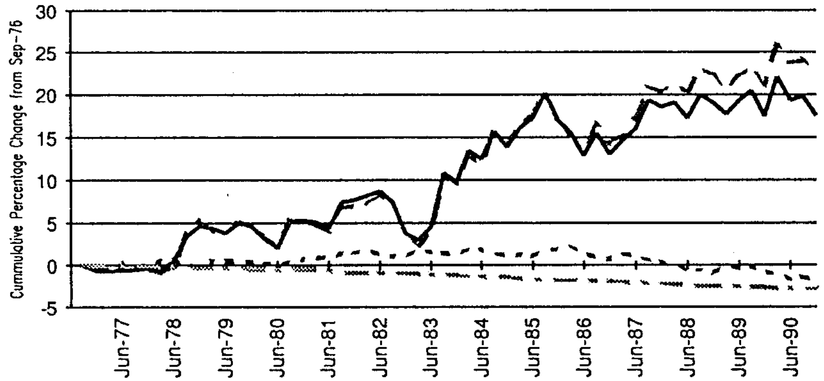
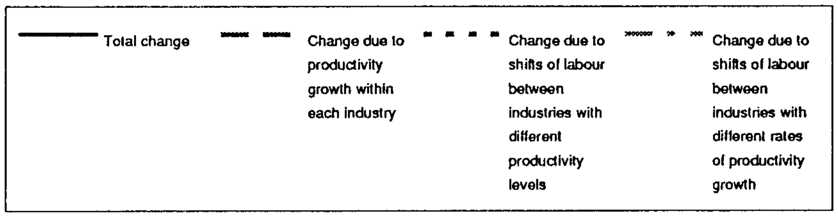


Chart 3B: Decomposition of Productivity Growth: Industries with Measurable Output





of total labour employed in each industry[11]. A shift of labour between industries occurs when there is a change in the shares of total labour employed in each industry. In this case, there will still be the two effects from the movement of labour, one due to the change in productivity levels and one due to the change in rates of productivity growth, but because it is no longer necessarily the case that all the labour that leaves one industry goes into one other industry, it is necessary to sum across all industries to obtain the aggregate impact from each of the effects[12].

III.ii A Decomposition of Changes in Labour Productivity

Performing this operation on Australian data using measures of gross product and employment which include data from all industries produces the results presented in Chart 3A. A number of points are worthy of comment. Most obvious is the extent to which movements in the aggregate labour productivity measure appear to be predominantly due to changes in labour productivity within each industry. This is particularly apparent with respect to cyclical movements which appear to be virtually unaffected by shifts of labour between industries over the course of the cycle.

Interestingly, however, since around June 1984 a gap has gradually opened up between the total and 'within industry' series so that by December 1990 there is a gap of about three and a half percentage points between the two. This is by no means insignificant when considered against a background rate of labour productivity growth of about one percent per annum.

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[11] Letting Y = gross product, L = employment, Lp = labour productivity and Ls = labour share, and using subscripts to denote industry level data:

$$Lp = \frac{Y}{L} = \frac{\Sigma Y_i}{\Sigma L_i} = \sum_i \left(\frac{Y_i}{L_i} \cdot \frac{L_i}{\Sigma L_i} \right) = \sum_i (Lp_i . Ls_i)$$

[12] The rate of change of aggregate labour productivity is given by:

$$\frac{\Delta Lp}{Lp_{t-1}} = \sum_i \frac{\Delta(Lp_i . Ls_i)}{Lp_{t-1}} = \sum_i \frac{\Delta Lp_i . Ls_{i,t-1}}{Lp_{t-1}} + \sum_i \frac{\Delta Ls_i . Lp_{i,t-1}}{Lp_{t-1}} + \sum_i \frac{\Delta Lp_i . \Delta Ls_i}{Lp_{t-1}}$$

The three terms give the effects on aggregate labour productivity of changes in labour productivity within each industry, of movements of labour between industries due to industries having different productivity levels, and of movements of labour between industries due to industries having different rates of productivity growth.

Chart 4A: Labour Productivity

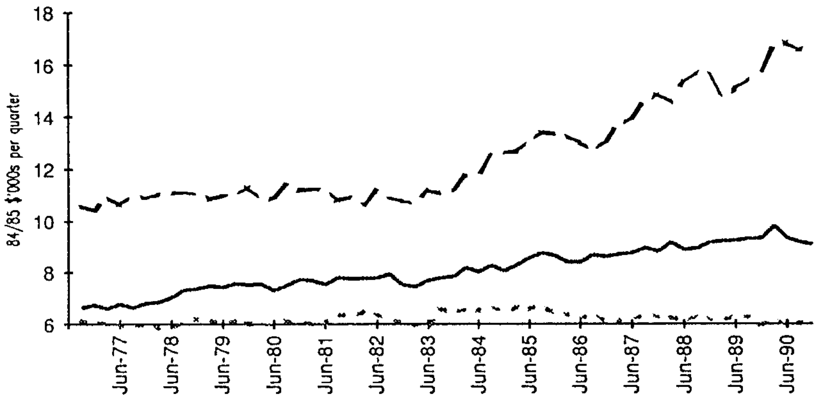
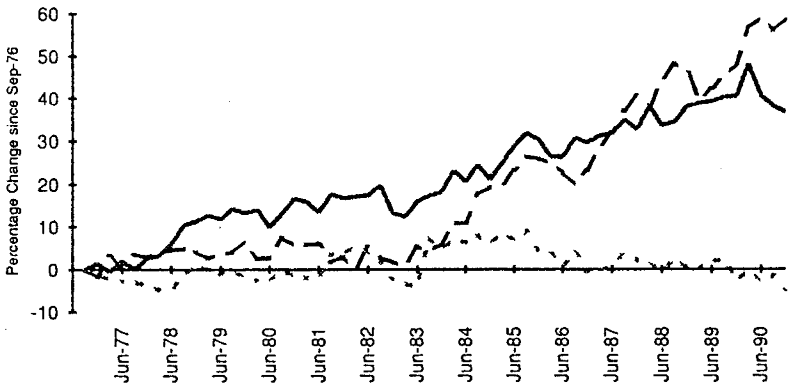


Chart 4B: Cumulative Change in Productivity



Manufacturing | Capital Intensive Industries | Labour Intensive Industries

Chart 5A: Employment Share

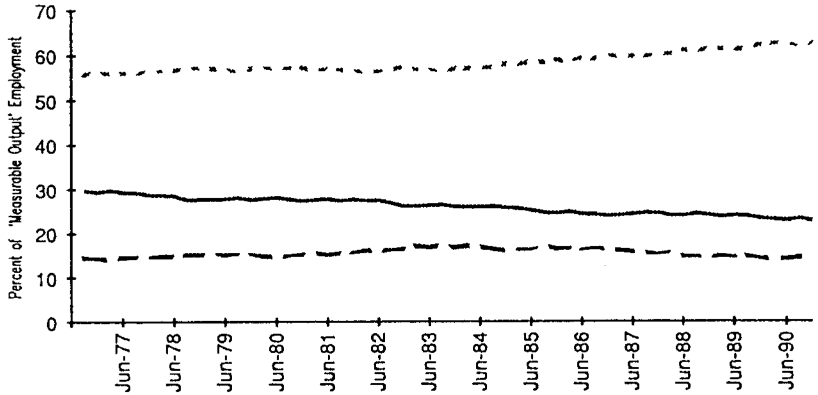
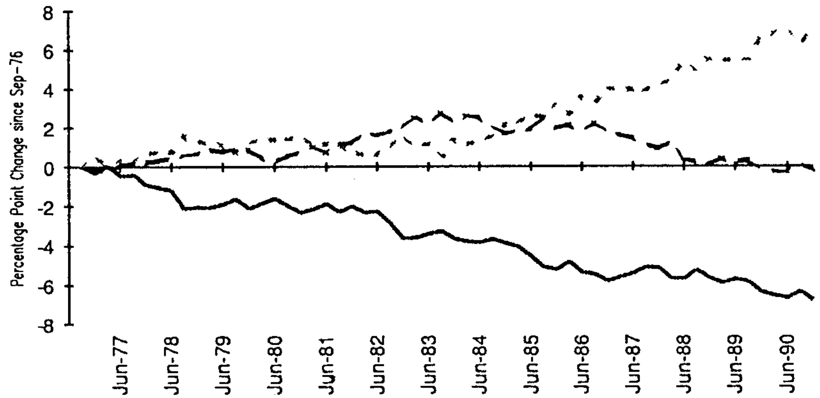


Chart 5B: Cumulative Change in Employment Share



Manufacturing | Capital Intensive Industries | Labour Intensive Industries

Looking at the other two series, it appears that the gap owes something to both types of effect of movements of labour between industries. On the one hand, there has been a fairly constant negative effect on aggregate labour productivity over the entire period due to shifts of labour from industries of higher to industries of lower rates of productivity growth, and it is this which provides most of the gap at the end of the data. On the other hand, the timing of the appearance of the gap is largely a product of the effect of movements of labour between industries of different productivity levels, since in the first half of the period a positive contribution from this tended to offset the negative impact from the former source.

One possible explanation of these results obvious to anyone familiar with Australian productivity data is in terms of the 'unmeasurable output' industries. Because of the difficulties in producing reliable output measures in the areas of *finance, property and business services, public administration and defence*, and *community services*, measures of gross product in these industries are simply formed by extrapolation using labour input. This has the unfortunate result for productivity analysis of removing any productivity growth in these industries by assumption (although they do, of course, retain a cost-based productivity *level*). To the extent that these industries may have been increasing in size over the period of the analysis, they might provide an explanation of the shift of labour into industries with lower rates of productivity growth.

This hypothesis can be tested quite easily by repeating the analysis using only industries with truly measurable output when constructing the aggregate measures of gross product and employment. The results of such an exercise are presented in Chart 3B. The strong similarity of this chart to the previous one suggests that these industries are not the driving force behind the observed effects from the shifting of labour between industries. Removing the industries does, however, have the predictable effect of increasing the rate of within industry productivity growth as the zero productivity growth assumed within these industries is no longer dragging down the total.

In order to provide an explanation of the results from the decomposition it is necessary to look at the data at a more disaggregated level. A useful way to do this is to divide the remaining industries into three classifications: firstly, *manufacturing* by itself; secondly, an aggregate of *mining, electricity, gas and water*, and *transport, storage and communication* (which will be referred to as the *'capital intensive industries'*); and, lastly, an aggregate of *agriculture, construction, wholesale and retail trade*, and *recreational services* (which will be referred to as the *'labour intensive industries'*).

Measures of the level of labour productivity and of the growth in labour productivity for each of these classifications are provided in Chart 4A and Chart 4B. There are two points worth noting. Firstly, there is substantial variation in the level of labour productivity across these classifications. The *capital intensive industries* have an average productivity level around two and a half times higher than the *labour intensive industries*, while *manufacturing* is somewhere in between. Secondly, there is a vast difference in the rate of growth of labour productivity of the different classifications. In particular, while both *manufacturing* and the *capital intensive industries* have experienced labour productivity growth of around forty to fifty percent over the fourteen year period, the *labour intensive industries* have experienced more or less no labour productivity growth at all.

The second set of disaggregated data required to interpret the results from the decomposition of labour productivity is that of the employment share of industries. Chart 5A and 5B contain the level and the cumulative change of employment share using the three classifications defined above. Of particular interest are the substantial changes in employment share depicted in Chart 5B. The employment share of *manufacturing* persistently declined throughout the period. In the first half of the data, this was offset by an increase in the employment share of the *capital intensive industries*. In the second half of the data, however, the labour share of the *capital intensive industries* returned to its original level, and the offsetting role was played by the *labour intensive industries* which experienced very rapid growth in employment share.

An explanation of the results obtained from the decomposition of labour productivity growth can be constructed fairly readily from these two sets of data. From 1976 to 1984 there was little impact of changes in industry composition on the aggregate labour productivity growth because of two offsetting effects. On the one hand there was a negative impact on aggregate labour productivity from declines in the labour share of *manufacturing*, as this meant that people were being moved to industries with lower rates of productivity growth. On the other hand there was a positive impact on aggregate labour productivity from the increase in the employment share of the *capital intensive industries*, since the level of labour productivity in these industries was considerably higher than in the *labour intensive industries*.

After 1984, however, the latter of these two effects was reversed as the *capital intensive industries* started to lose labour share. The growth in labour share of the *labour intensive industries*, which had low levels of productivity and little productivity growth, had a substantial impact on conventionally measured aggregate labour productivity. It is this effect which explains the divergence between actual and industry composition adjusted measures of labour productivity growth contained in Chart 3A and Chart 3B.

III.iii A Decomposition of Changes in the Capital to Labour Ratio

The same type of analysis can be applied to what our results in Section II indicate is one of the principal influences on aggregate labour productivity, the aggregate capital to labour ratio. The method is exactly the same as before with the aggregate capital to labour ratio conceptualised as a weighted sum of the capital to labour ratio within each industry where the weights are given by the share of total employment in the industry. Again, there are two effects of shifts in employment on the aggregate capital to labour ratio. Firstly, there is the effect of shifting labour between industries with higher and lower *levels* of capital to labour. Secondly, there is the effect of shifting labour between industries with higher and lower *rates of growth* of capital to labour.

The results of applying this analysis to the Australian economy over the period September 1976 to June 1990 are presented in Chart 6A, which shows the analysis applied to aggregates containing all industries, and Chart 6B, which shows the analysis using aggregates containing only industries with measurable output. In both cases the fairly striking result suggested is that the flattening of the capital to labour ratio that occurred around June 1983 would not have occurred if the same changes had taken place in the capital to labour ratio within each industry but industry composition had remained unchanged.

Again, an explanation of this can be found fairly readily in the disaggregated data. Charts 7A and 7B present the level and cumulative change in the capital to labour ratio for the three classifications of industries defined above. Immediately noticeable from Chart 7A is the very high capital to labour ratio of the *capital intensive industries* (hence its name) when compared to those of the remaining classifications. In fact, on average, it is about four times higher than that of the *manufacturing* industry and about five times higher than that of the *labour intensive industries*. The story in Chart 7B is slightly more complicated. Both *manufacturing* and *labour intensive industries* have rapid growth in the capital to labour ratio during the first half of the period followed by either roughly constant or slightly negative growth in the second half of the period. The *capital intensive industries*, on the other

Chart 6A: Decomposition of Changes in the Capital to Labour Ratio: All Industries

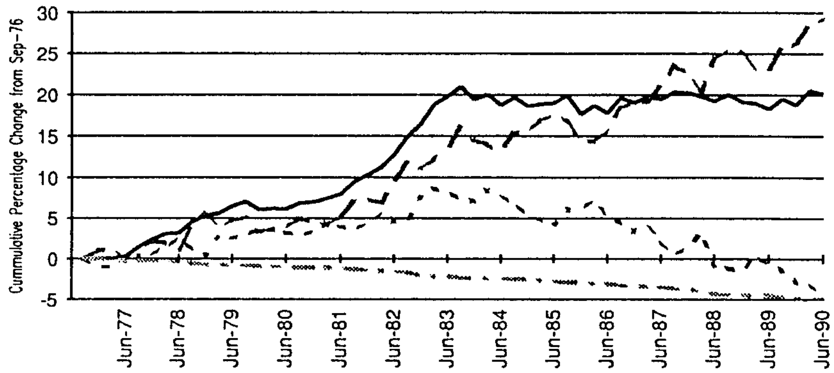
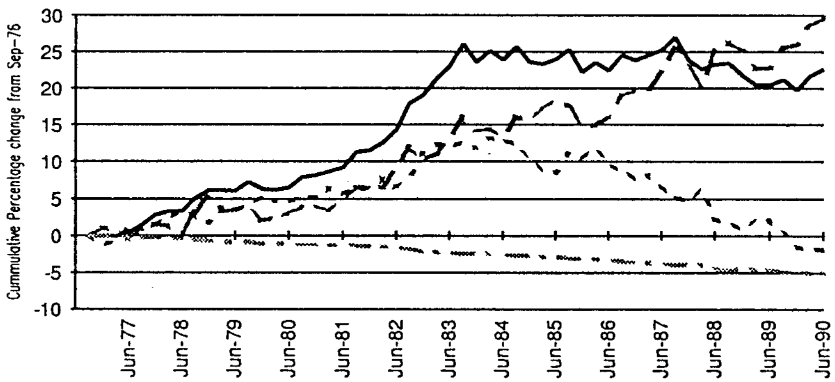


Chart 6B: Decomposition of Changes in the Capital to Labour Ratio: Industries with Measurable Output



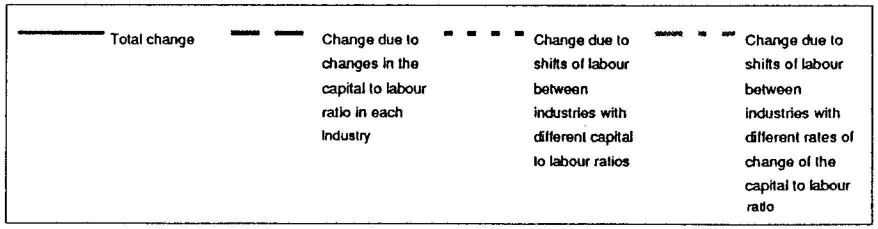


Chart 7A: Capital to Labour Ratio

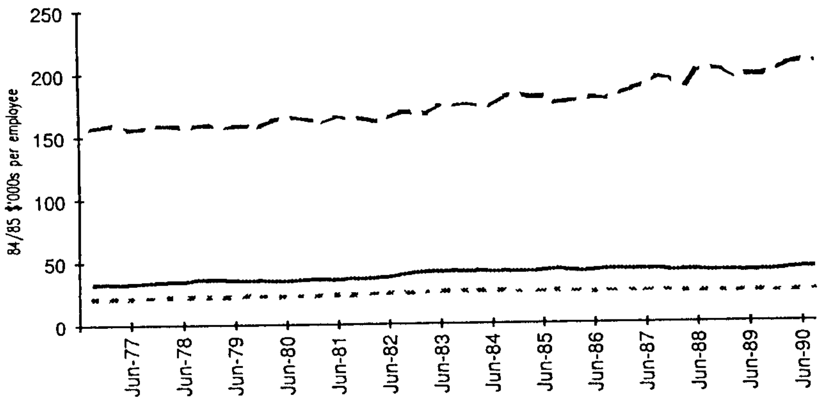
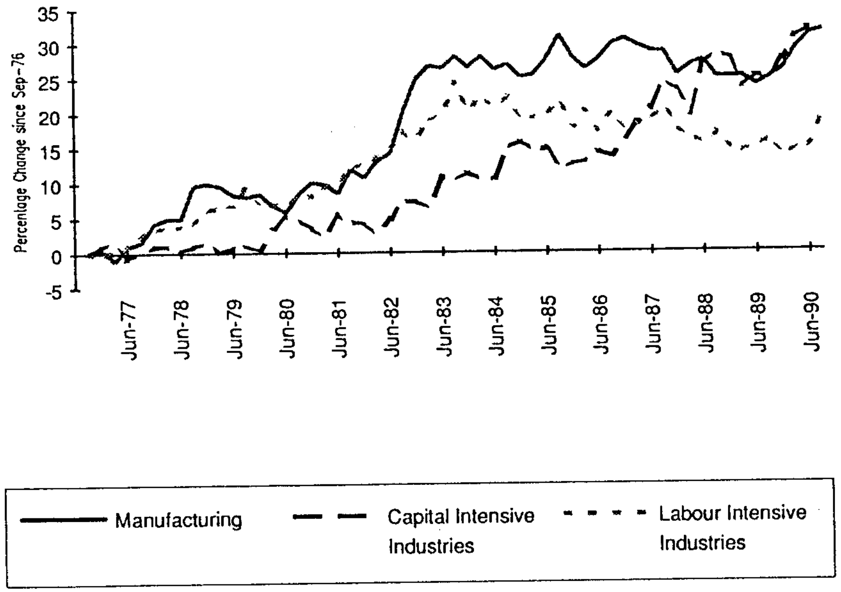


Chart 7B: Cumulative Change in the Capital to Labour Ratio



hand, after a slow start, show fairly firm growth in the capital to labour ratio throughout the period.

Referring back to chart 5B, the following explanation of the results from the decomposition of the capital to labour ratio can be suggested. Of primary importance is the role of the *capital intensive industries*. Since there is a very large difference between the capital to labour ratio in this classification and in the *labour intensive* one, any shifts of labour in or out of this classification will have a substantial effect on the aggregate ratio. It is precisely such an effect which is captured by the results from the decomposition. In particular, Chart 6A and Chart 6B suggest that from 1976 to 1984 the aggregate capital to labour ratio was boosted around ten percentage points due to the rise in the labour share of the *capital intensive industries*. After 1984, however, the gradual return of the labour share of these industries to their initial level reversed this effect, causing the gap between the total and within industry capital to labour ratio series to close up.

There is also a secondary effect which can probably be attributed to the long term loss of employment share of *manufacturing* to the *labour intensive industries*. By the end of the period, the lower levels and rates of growth of the capital to labour ratio in the latter classification appear to have resulted in a mild negative compositional effect on the aggregate ratio.

IV Conclusions

The data in Table 1 indicate that labour productivity growth, as measured by output per person employed, fell from over 2.5% pa in the 1960s to around 1.8% pa in the 1970s and to less than 1% pa in the 1980s. The cointegration analysis of Section II suggests that, at an aggregate level, there was a strong correlation between labour productivity and the capital to labour ratio. In fact, the slowdown of productivity growth in the 1980s appears entirely attributable to a slowdown in growth of the capital to labour ratio rather than to a slowdown in total factor productivity growth (as appeared to be the case in the 1970s).

The results obtained from the disaggregated data suggest a number of difficulties with this explanation, or at the very least remind us of the hazards involved in using aggregate statistical relationships for policy-making.

Firstly, looking at the disaggregated series for our three classifications, there are a number of curious results. While the *capital intensive industries* show a reasonable correlation between changes in labour productivity and changes in the aggregate capital to labour ratio, the other two classifications are slightly more puzzling. Most noticeably, the *labour intensive industries* show firm growth in the capital to labour ratio, at least over the first half of the period, but ends up with close to no productivity growth. *Manufacturing* also shows a marked flattening of the capital to labour ratio in the second half of the data, but its labour productivity seems to be little affected by this decline. In general, the correlations between labour productivity and the capital to labour ratio at a more disaggregated level do not appear to be very good.

Secondly, with respect to the effects on aggregate Y/L and K/L of changes in industry composition, since changes in industry composition have affected both aggregate labour productivity and the aggregate capital to labour ratio in a broadly similar fashion, it is hardly surprising that there is an obvious correlation between the two. However, although the flattening of capital to labour ratio correlates with the slowdown in labour productivity growth, this should not be interpreted as indicating a type of substitution by each firm in the economy of labour for capital. To the extent that a type of aggregate substitution is apparent, this seems to reflect movements in industry composition not substitution within each industry.

This has interesting implications with respect to a slightly different question, that of whether the flattening of the capital to labour ratio since June 1983 can be considered as a response to the real wage restraint engineered under the Accords I-VI negotiated between the Labour Government and the Australian Council of Trade Unions. This seems unlikely for the following reason. While it would be possible for a change in relative factor prices to cause a form of aggregate substitution of capital for labour by altering the compositional balance between industries, even though the capital to labour ratio in each industry was fixed, this does not sound convincing with respect to the particular movements of labour in question in this case. This is because the industries involved, *mining, electricity, gas and water*, and *transport, storage and communications* (our *capital intensive industries*) tend to have their own unique influences affecting their relative growth. *Mining* is heavily influenced by world commodity prices, while *electricity, gas and water* and *transport, storage and communications* are strongly influenced by their largely public sector origins. The neoclassical substitution story that there was a relative price induced demand shift from the output of the *capital intensive industries* to the output of the less capital intensive industries, seems a little far fetched in this case. At any rate, some caution is certainly necessary in advocating this interpretation of productivity movements in the 1980s. If our argument is persuasive, the various Accords should not be judged on the basis of changes in productivity.

One major lesson of this work is that the results of aggregate empirical analysis of productivity change need to be interpreted with some caution. Disaggregation suggests that changes in industry composition were important causes of the slowdown in growth of both labour productivity and the capital to labour ratio after 1983. More fundamental explanations of productivity growth should be revealed by further disaggregated analysis.

If the level and growth of productivity were the only policy objectives, our results suggest that there would be an 'optimal industry composition'. The effect of industry composition is over and above the standard sources of productivity improvements arising out of capital deepening and technological progress. As far as the level of productivity goes, it would seem that a reversal of the decline of the share of the major public utilities in the 1980's would make a substantial improvement in the level of measured productivity at constant prices. However given inelastic demand for their output, this would not necessarily indicate an increase in social welfare. For productivity growth, a similar argument would apply to increasing the labour share of the manufacturing sector.

Finally, the strikingly different rates of productivity growth across industries revealed by this study suggest that a wages policy which focuses on industry or enterprise bargaining is likely to lead to dramatically different rates of wages growth. This will almost certainly lead to tensions based on comparative wage justice. Resolution of these tensions will be inflationary and/or increase unemployment.

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