

Cashin, Paul A.

Working Paper

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Center Discussion Paper, No. 688

Provided in Cooperation with:

Yale University, Economic Growth Center (EGC)

Suggested Citation: Cashin, Paul A. (1993) : Economic Growth and Convergence Across the Seven Colonies of Australasia: 1861-1991, Center Discussion Paper, No. 688, Yale University, Economic Growth Center, New Haven, CT

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<https://hdl.handle.net/10419/160610>

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ECONOMIC GROWTH CENTER

YALE UNIVERSITY

Box 1987, Yale Station
27 Hillhouse Avenue
New Haven, Connecticut 06520

CENTER DISCUSSION PAPER NO. 688

ECONOMIC GROWTH AND CONVERGENCE
ACROSS THE SEVEN COLONIES OF AUSTRALASIA:
1861-1991

Paul A. Cashin

Yale University

May 1993

Note: Center Discussion Papers are preliminary materials circulated to stimulate discussions and critical comments. This paper is taken from Chapter 3 of the author's Ph.D. dissertation in the Economics Department at Yale University entitled "Essays on Economic Growth: The Effect of Government on Growth, and an Analysis of Growth in, and Convergence Across, the Seven Colonies of Australasia."

Research for this paper was partly funded by the Australian Pig Research and Development Corporation and a Doctoral Dissertation Fellowship from the Alfred P. Sloan Foundation.

I especially thank Gustav Ranis, Xavier Sala-i-Martin and T.N. Srinivasan for their comments and suggestions.

Abstract

In this paper I analyse the process of economic growth among the seven colonies of Australasia (Australia and New Zealand) during the 1861–1991 period. In particular, I examine whether there has been convergence in per-capita incomes across the colonies. The two main concepts of convergence in the levels of per-capita income (β -convergence: how fast do initially-poor economies 'catch up' to initially-rich economies?, and σ -convergence: does the cross-sectional dispersion of per-capita incomes diminish over time?) are discussed and it is found that the colonies have indeed been converging to one another, using either concept. After controlling for the differing sectoral compositions of the colonies, it is found that the initially-poor colonies have been converging on the initially-rich colonies at the rate of about 2.74 per cent per year. The cross-sectional dispersion of per-capita incomes has also been declining over the period, but it appears most of this decline occurred in the 1861–1901 period, as the extent of dispersion in 1991 is very close to that attained in 1901.

KEY WORDS: Economic growth; convergence; Australia and New Zealand.

1. Introduction

This paper undertakes an examination of the trend of regional growth patterns across the seven colonies of Australasia (Australia and New Zealand) during the period 1861–1991. The economic growth of the Australasian colonies is of interest because of its unusual combination of: the early orientation of economic activity towards specialisation in the urban-based commercial/manufacturing and service sectors of the economy; the extremely rapid rate of urbanisation of colonial populations⁰; the small size of these initial populations relative to the large land area; large-scale migration (hence maintaining a higher than normal share of the total population in the labour force); abundant natural resources (minerals and grazing land) accompanied by the invention and adoption of capital-intensive agricultural and mining technologies (which yielded very high labour productivity); dependence on large foreign capital flows (domestic savings were supplemented by large flows of British savings); and heavy investment of these savings in the provision and maintenance of public infrastructure. This mix was so successful that by the early 1860s Australia and New Zealand had clearly surpassed the United Kingdom in attaining the highest GDP per capita among the (currently) advanced capitalist countries, and maintained that position until they in turn were surpassed by the United States, sometime during the years of the

⁰ By 1891 almost two-thirds of the population of the three largest colonies lived in cities and towns; the United States attained this fraction in 1920, and Canada only in 1950 (Butlin 1964).

First World War (see Figure 1, Table 1, Butlin 1970, Maddison 1982, Baumol 1986, and De Long 1988)¹².

The rapid growth of real GDP during the 19th and 20th centuries transformed the independent colonies of Australasia into prosperous regional economies of two independent countries, and this process of growth will be analysed in this paper. However, as noted in Cashin (1993a), most previous analyses of economic growth in Australasia had to be conducted at the national level (such as Dowrick and Nguyen 1988), due to the absence of a consistently-derived series for the aggregate incomes of the seven regional economies.

Whilst there are many studies of the international processes of growth and convergence for the OECD countries (see Baumol 1986, DeLong 1988, Dowrick and Nguyen 1989, and Barro 1991 among others), there are relatively few such works examining regional growth patterns within any given country. Exceptions have been Easterlin (1957, 1960), Williamson (1965) and Barro and Sala-i-Martin (1992) for the states of the United States of America, Williamson (1965) and Barro and Sala-i-Martin (1991) for the regions of Europe, De Gregorio (1991) for several

¹ Maddison's (1977) data reveal that Australia's GDP per capita as a percentage of US GDP per capita was 173 in 1870, while the corresponding figure for Britain relative to the US was 124. In 1890 (1913) the corresponding figures were 145 (107) for Australia, and 103 (81) for Britain. By 1929 the figures were 74 for Australia and 67 for Britain, and Australia's per-capita income has basically remained at that percentage of US GDP per capita ever since.

² Maddison's (1977, 1979, 1982) data bring out the point that while Australia's real GDP grew at an annual average compound rate of 3.308 per cent between 1860-1979 (the 3rd-highest in his 16-country sample), its population grew at a rate of 2.150 per cent (by far the highest rate in the sample) and so real GDP per capita only grew at 1.09 per cent (the lowest in the sample). In contrast, the relevant figures for the United States are, respectively: 3.444 (second-highest), 1.635 (third-highest) and 1.782 (eighth-highest) per cent. For further details see Table 1.

South American nations, and Barro and Sala-i-Martin (1992a) and Shioji (1993) for the prefectures of Japan.

By undertaking an analysis of the seven Australasian economies, it is hoped that one can minimize problems which would arise if the various economies exhibited different steady-state real GDP per capita. Given that all seven colonies are likely to possess similar levels of technology and similar preferences, and the fact that there existed a relatively unfettered flow of both capital and labour across colony borders, one would expect all colonies to have similar real per-capita GDPs in the steady state. Accordingly, in this case absolute convergence should be closely approximated by conditional convergence.

Note that the closed economy model of convergence obviously cannot be applied literally to the Australasian colonies, because for given technologies convergence in both per-capita GDP and capital stocks will occur faster in open than in closed economies. However, as shown by Barro, Mankiw and Sala-i-Martin (1992), in the presence of imperfect capital markets which constrain only a fraction of physical capital to be able to serve as collateral for investment by governments and/or individuals, GDP exhibits very similar behaviour to that which would be predicted by the closed economy model of this and other papers. That is, partial capital mobility in an open-economy version of the neoclassical growth model can explain the gradual incidence of convergence in GDP. It should also be noted that while these constraints on the role of collateral were undoubtedly present, the Australasian colonies were in the advantageous position of having (for much of the 1861-1991 period) the world's largest net exporter of capital as their 'mother' country.

Answers to two key questions will be explored in this paper. First, did the initially-poor colonies of Australasia subsequently grow faster than the initially-rich colonies? Second, has the cross-sectional dispersion of per-capita

incomes across the colonies grown or diminished over the period of analysis? I find evidence supporting the conjectures of the neoclassical growth model of Solow (1956) and Swan (1956): the poor colonies did indeed grow faster, and have been converging towards the rich colonies at a rate of 2.74 per cent per year (assuming a common steady state for all colonies). There has also been a secular decline in the cross-sectional standard deviation of the logarithm of per-capita incomes (that is, a decline in the coefficient of variation) over the period 1861-1991, and most of this decline occurred in the period 1861-1901.

Section 2 will discuss the concepts of convergence to be used in this paper, while Sections 3 and 4 present estimates of the speed of convergence of the poor colonies to the rich, and some associated *caveats* arising from the estimation of colonial GDP by the monetary-based technique of Cashin (1993, 1993a). Similarly, Sections 5 and 6 present estimates of the dispersion of per-capita GDP across the colonies, and associated *caveats* flowing from use of the monetary-based technique. Section 7 analyses in greater detail those sub-periods during which the dispersion of per-capita GDP across the colonies grew rather than diminished, and Section 8 offers some concluding comments.

2. Concepts of Convergence

Barro and Sala-i-Martin (1992) take a Cobb-Douglas production function in units of effective labour, and a representative consumer with a utility function exhibiting constant intertemporal elasticity of substitution, log-linearise the resultant equations of motion about the steady state and derive the dynamic equation for the average growth rate of per-capita output, y , over any given interval between 0 and T :

$$(1) \quad T^{-1} \ln(y_T/y_0) = (1 - e^{-\beta T}) T^{-1} \ln[\hat{y}^*/\hat{y}_0] + x,$$

where β is the speed of convergence, T is the length of the time interval, \hat{y} is output per unit of effective labour, the * superscript denotes steady-state values, and x is the exogenous rate of labour-augmenting technical progress. In (1) convergence is conditional, as what drives β is the level of \hat{y}_0 for each economy relative to its own \hat{y}^* and x , which need not be homogeneous across economies. The probability of such homogeneity is, however, greater for regions of a given country, which are more likely to share common levels of technology and common preferences³.

If we assume the level of technology is likely to be uncorrelated with initial income, and that technologies are relatively homogeneous across colonies, then y_0 can be substituted for \hat{y}_0 in (1). Accordingly, a version of (1) that applies for discrete periods for any given economy i gives the (geometric) average growth rate over the interval $t-T$ and t as:

$$(2) \quad T^{-1} \ln(y_{it}/y_{i,t-T}) = C - T^{-1} [\ln(y_{i,t-T})] (1 - e^{-\beta T}) + \text{other variables} + \mu_{it},$$

where i indexes the economy, T is the length of the observation interval, t is time, $y_{i,t-T}$ is per-capita real GDP for each economy at the beginning of the sub-period, $t-T$; y_{it} is the real per-capita GDP at time t ; β is the convergence coefficient; μ_{it} is a distributed lag disturbance term, and C is a constant term with $C = x + [(1 - e^{-\beta T})/T] [\ln(\hat{y}^*) + xT]$, which is independent of i if we assume all

³ The notion of homogeneous technology across regions of a given country may break down if we widen the definition of 'technology' to embrace endowments of natural resources and government policies which affect the net return to producers (through the enforcement of property rights and the levying of taxation). Serendipity in resource endowments and differential fiscal policies can thus induce heterogeneous technology across otherwise similar regional economies.

Australasian colonies have similar underlying preferences and technology, and so will have the same steady-state levels of real per-capita GDP and the same steady-state growth rates: thus, $x = x_i$ and $y = y_i^*$. Note that in (2) it is assumed that μ_{it} is distributed independently of both $\ln(y_{i,t-T})$ and μ_{jt} , $i \neq j$.

There are two common measures of convergence which follow from equation (2). The first, known as β -convergence, asks whether initially-poor economies tend to grow faster than initially-rich ones (that is, whether there is mean reversion in the level of real per-capita GDP across economies). Another concept is σ -convergence, which considers the decline of the cross-sectional dispersion of real GDP per capita over time (that is, whether the standard deviation of the logarithm of per-capita GDP (the coefficient of variation) across economies is shrinking). Barro and Sala-i-Martin (1992) note that β -convergence is a necessary but not a sufficient condition for σ -convergence, as a positive β will tend to reduce σ_t , (the dispersion of $\ln(y_{it})$ in (2)), for a given distribution of μ_{it} , but new exogenous shocks to μ_{it} will tend to raise σ_t .

For example, a large relative fall in the price of agricultural commodities (as opposed to the price of non-agricultural commodities) during wartime would reduce the value of real output (akin to an income effect) in agriculture-based regions. Conversely, it would raise the value of output for those regions which did not have a relatively large agricultural sector. Such relative price shocks alter the distribution of the error term, μ_{it} , so that μ_{it} is no longer distributed independently of μ_{jt} for regions i and j . Such shocks thus tend to raise the values of σ_t temporarily above its steady-state value, σ . However, given that the steady-state distribution of μ_{it} does not change, following any given shock $\sigma_t \rightarrow \sigma$ over time.

Omitted variable bias can result if, for example, such exogenous shocks to agricultural prices differentially affect the more rural-based Australasian colonies.

If such colonies were initially poor, then an adverse price shock would induce underestimation of the subsequent speed of convergence, β , as the omitted (shock) variable would be positively-correlated with initial income ($y_{i,t-T}$). Moreover, the main sectoral shift of employment in the colonial economies over this period was from agriculture to other sectors (principally mining, manufacturing and services). As economies develop, workers generally shift out of agriculture, and if these other sectors have higher labour productivity than agriculture, then this shift alone in the pattern of the workforce would generate growth in those colonies with initially-high shares of their labour force in agriculture (Kuznets 1966). Hence I include the share of each colony's workforce employed in agriculture to control for the sectoral composition of colonial production. This rural employment variable would also be expected to control for shocks which have common effects on sub-groups of colonies - such as a relative decline in the fortunes of the agriculture-based colonies in the 1890s due to drought conditions existing in Australia over much of that decade.

3. Analysis of β -Convergence Across the Colonies

The first task of this empirical section is to analyse the pattern of β -convergence of real per-capita GDP across the seven Australasian colonies. Column 1 of Table 2 reports the regression estimates of the convergence coefficient ($\hat{\beta}$) in (2), and in all column 1 regressions only a constant term (not reported) and the logarithm of initial sub-period income are the explanatory variables. Note that a positive coefficient for β can be translated as initially-poor colonies growing faster than initially-rich ones. The mean and standard deviation of all variables used in this Section are listed in Appendix A.

The first row of column 1 reports the results for a single regression on the whole period, 1861–1991, and it is found that $\hat{\beta}=0.0077$ [s.e. 0.0016] is the result, with an adjusted R^2 of 0.789 and standard error of the regression of 0.0012. The negative correlation between the logarithm of per-capita income in 1861 and the subsequent 1861–1991 growth rate can also be seen in Figure 2.

Single equation regressions are then run for both the 1861–1901 and 1901–1991 periods. It is found that $\hat{\beta}$ for both sub-periods has the expected sign. The estimated β coefficient in the former sub-period is statistically significant and more rapid than for the full period ($\hat{\beta}=0.0223$ [s.e.=0.0036]), while for the latter sub-period the estimated coefficient is relatively slower ($\hat{\beta}=0.0023$ [s.e.=0.0055]). In row seven of column 1 a multivariate regression on the above two-equation system yields a constrained estimate for the two sub-periods (1861–1901 and 1901–1991) of $\hat{\beta}=0.0196$ [s.e.=0.0024]. A Wald test (W) for the null hypothesis of equal β -coefficients in the two sub-periods is weakly rejected (W statistic=6.03, p-value=0.014). Figures 3 and 4 depict the negative correlation between initial income and the subsequent growth rate for these two sub-periods. The relatively poor growth performance of NZ in the 20th century stands out in Figure 4.

The apparent instability of the convergence coefficients in the above two sub-periods could be the result of aggregate shocks which differentially affected sub-groups of the seven colonies (as mentioned in Section 2 above). Hence, column 2 of Table 2 introduces the workforce in the agricultural sector of the economy as a share of each colony's total workforce as a variable to control for aggregate shocks to agricultural prices. When this variable is added the coefficients on initial income in both sub-periods again have the expected signs, and again one of them is significant. The restricted coefficient on the system is now $\hat{\beta}=0.0269$ [s.e.=0.0022], and the Wald test for equality of the coefficients in both sub-periods is not rejected (W=2.215, p-value=0.1367).

The rows of column 3 of Table 2 divide the 1861–1991 period into three sub-periods: 1861–1891 (prior to the Depression of the 1890s), 1891–1947 (covering two Depressions and two World Wars) and 1947–1991 (the post-Second World War period). It is found that the estimated β -coefficients for all sub-periods again have the appropriate sign and all are significant, although the speed of convergence is relatively slow ($\hat{\beta}=0.016$ [s.e.=0.0064]) for the sub-period 1891–1947. A multivariate regression on the three-equation system yields in row seven a constrained estimate of $\hat{\beta}=0.0194$ [s.e.=0.0019], which, when tested for the null hypothesis of the same $\hat{\beta}$ -coefficient in all three sub-periods, is rejected ($W=16.58$, p-value=0.0003). In column 4 the agricultural share of the labour force variable is added to control for aggregate price shocks, and now the single equation estimates all have estimated β -coefficients of similar speed. It should also be noted that the rural labour force variable (not reported) is negative and significant in the latter two sub-periods. The restricted coefficient in the multivariate regression has a value of $\hat{\beta}=0.0274$ [s.e.=0.0020], and a test for the equality of the estimated β -coefficients across the three regressions is not rejected ($W=3.300$, p-value=0.1920). The latter value for $\hat{\beta}$ implies a half-life of the logarithm of per-capita income (the time it takes for one-half of the gap between any initial per-capita income and the steady-state per-capita income to be closed) of 25.55 years.

Note that in columns 3 and 4 it is the period 1947–1991 which exhibits the fastest speed of convergence ($\hat{\beta}=0.0312$ [s.e.=0.0074] in column 4). The relative decline in agricultural commodity prices since the Second World War can be argued to have hurt those economies specialising in such products. A particular case in point is NZ. In 1947 NZ was the richest (in per-capita income terms) of all the colonies (see Table 4, Cashin (1993a)), but since then has declined to be in 1991 clearly the poorest of the seven colonies. The decline in the prices of the

agricultural commodities on which NZ was relatively more dependent has thus contributed to a faster rate of β -convergence among the seven economies in this period.

The estimated speed of convergence for the Australasian colonies ($\hat{\beta}=0.0274$) is slightly faster than that found in some earlier studies of regional economies: the states of the United States ($\hat{\beta}=0.0249$) between 1880–1988 by Barro and Sala-i-Martin (1992); the regions of European OECD countries ($\hat{\beta}=0.0178$) between 1950–1985 by Barro and Sala-i-Martin (1991); European and non-European OECD countries ($\hat{\beta}=0.0097$) between 1971–1988 in Cashin (1993); and 98 (OECD and non-OECD) countries ($\hat{\beta}=0.0111$) between 1960–1985 by Barro (1991); but slightly slower than that found for the prefectures of Japan ($\hat{\beta}=0.034$) between 1930–1987 by Barro and Sala-i-Martin (1992a), and for Japan again ($\hat{\beta}=0.033$) between 1960–1988 by Shioji (1993). The present findings fit into the hierarchy of convergence speeds hypothesised by Barro and Sala-i-Martin (1991): that the more heterogeneous the steady states to which a group of economies are converging, the slower the speed, even after controlling for the disparate steady states. That is, regions of a given country (such as the United States, Japan and Austral(as)ia) should exhibit the fastest convergence, followed by similar national economies (such as the OECD), followed by all national economies. Faster intra-national speeds of convergence are also partly induced by greater degree of labour mobility, which is evident here in the colonial population growth rates of Table 6 of Cashin (1993a) and the intercolonial migration data of Table 1 of Cashin (1993a).

The fact that we observe β -convergence in Australasia without controlling for differences in steady-state colonial growth rates or levels of per-capita incomes is indicative of homogeneity across colonies with respect to steady states (and/or substantial labour mobility across colonies), yet heterogeneous initial levels of

per-capita colonial incomes. Hence, absolute and conditional convergence in the Australasian colonies do appear to be almost synonymous.

4 Implications for β -Convergence of Measurement Error in the Monetary-Based Estimates of GDP

It is well known that errors in the measurement of explanatory variables will result in biased regression estimates of key parameters. An obvious candidate for such errors is initial income, $\ln(y_{i,t-T})$, which is the sole explanatory variable (along with a constant term) on the right-hand side of the basic β -convergence equation (2)⁴.

As noted in Cashin (1993a), in calculating the colonial nominal GDP use is made of the Australian income velocity of money. This could impart a bias to the β -coefficient on initial real per-capita colonial GDP in (2), to the extent that the individual colony velocities (V_i) are not closely approximated by the Australian velocity (V_a).

The true nominal GDP for colony i in period t is given by:

$$(3) \quad M_{it} V_{it} = Y_{it},$$

⁴ Another cause of potential bias is the use of a national deflator to adjust nominal colonial GDP figures for the rate of change of prices. That is, where P_a (the rate of change of Australian (all-colony) prices) is used rather than P_i to derive real GDP for each colony from nominal colony GDP, if prices differ across colonies at points in time, the correlation between P_a and the error term will induce bias in the estimated coefficients. However, there are no available price series for the colonies during the 1861-1900 period, and post-1900 data reveals that prices generally moved together in all colonies. Moreover, the use of a common (national) deflator for each colony at each point in time in cross-sectional analysis will affect only the constant term in each regression.

where M is the colonial stock of money, V the income velocity of money, and Y is the true colony nominal GDP, for $i=(NSW, VIC, QLD, SA, WA, TAS, NZ)$. When the Australian velocity is used instead, then the estimated colony GDP is:

$$(4) \quad M_{it} V_{at} = \hat{Y}_{it},$$

where V_a is the Australian income velocity of money, and \hat{Y}_i is the estimated nominal colonial GDP. Hence (4) can be rewritten as:

$$(5) \quad \hat{Y}_{it} = M_{it} V_{at} = (Y_{it}/V_{it}) V_{at} = Y_{it} (V_{at}/V_{it}),$$

and in per-capita terms (where L_i is the population of colony i):

$$(6) \quad \hat{y}_{it} = \hat{Y}_{it}/L_{it} = (Y_{it}/L_{it}) \cdot (V_{at}/V_{it}) = y_{it} \cdot (V_{at}/V_{it}).$$

In estimating the basic regression of (2), we have an assumed 'true regression' of:

$$(7) \quad T^{-1} \ln(y_{it}/y_{i,t-T}) = \alpha - \beta \ln(y_{i,t-T}) + \epsilon_{it},$$

where α is the constant term, β the convergence coefficient and ϵ the true disturbance term. When using the monetary-based technique, the actual 'estimated regression' is:

$$(8) \quad T^{-1} \ln(\hat{y}_{it}/\hat{y}_{i,t-T}) = \hat{\alpha} - \hat{\beta} \ln(\hat{y}_{i,t-T}) + \hat{\epsilon}_{it},$$

where $\hat{\alpha}$ and $\hat{\beta}$ are the estimated coefficients and $\hat{\epsilon}$ is the estimated disturbance

term. Accordingly, after substituting in (6), equation (8) can be rearranged to give:

$$(9) \quad T^{-1} \ln[(\hat{y}_{it}(V_{at}/V_{it})) / (y_{i,t-T}(V_{a,t-T}/V_{i,t-T}))] = \hat{\alpha} - \hat{\beta} \ln(y_{i,t-T}(V_{a,t-T}/V_{i,t-T})) + \epsilon_{it}$$

Hence, when $V_{at} = V_{it} \forall t$, estimating (7) will yield the same result as estimating (8) or (9). However, when $V_{at} \neq V_{it}$ then while we should be using $y_{i,t-T}$ as initial income in (7), we are instead using $y_{i,t-T} / (V_{i,t-T}/V_{a,t-T})$, as in (9). There are two cases to examine: when $\ln(\hat{y}_{it})$ as measured by the monetary-based technique is used to estimate the true $\ln(y_{it})$ for all t ; and where the true $\ln(y_{i,t-T})$ is given in the initial period (or where $\ln(\hat{y}_{i,t-T})$ is measured without error), and then the monetary-based technique is used to 'fill in' missing values for all subsequent estimates of $\ln(y_{it})$. As the former case is relevant here, it will be emphasised below, with the latter case largely discussed in Appendix B.

4.1 Error in the Estimation of $\ln(y_{it})$ for All Periods

With $\ln(\hat{y}_{it})$ measured with error by the monetary-based technique for all periods (including the initial period, $y_{i,t-T}$), then the resultant OLS estimate of $-\hat{\beta}$ in (9) will be given by:

$$(10) \quad -\hat{\beta} \equiv \frac{\text{cov}[\ln(y_{i,t-T}) + \ln(V_{a,t-T}) - \ln(V_{i,t-T}), T^{-1}(\ln(\hat{y}_{it}) + \ln(V_{at}) - \ln(V_{it}) - \ln(y_{i,t-T}) - \ln(V_{a,t-T}) + \ln(V_{i,t-T}))]}{\text{var}[\ln(y_{i,t-T}) + \ln(V_{a,t-T}) - \ln(V_{i,t-T})]}$$

and given that $\ln(V_{at})$ is constant across the colonies then (10) becomes:

$$(11) \quad -\hat{\beta} \equiv \text{cov}[\ln(y_{i,t-T}) - \ln(V_{i,t-T}), T^{-1}(\ln(y_{it}) - \ln(V_{it}) - \ln(y_{i,t-T}) + \ln(V_{i,t-T}))] \\ / \text{var}[\ln(y_{i,t-T}) - \ln(V_{i,t-T})].$$

Denote $\varphi \equiv -[\partial \ln(V_{it}) / \partial \ln(y_{it})] > 0^5$, and if we assume η (and hence, φ) is constant, then $\ln(\hat{y}_{it}) = \ln(y_{it}) - \ln(V_{it}) = (1 + \varphi)\ln(y_{it}) + \text{constant}^6$. Substituting $(1 + \varphi)\ln(y_{it})$ for $\ln(\hat{y}_{it})$ in (11) yields, for $(1 + \varphi)$ constant:

$$(12) \quad -\hat{\beta} = T^{-1} \{ (1 + \varphi)^2 \text{cov}[\ln(y_{i,t-T}), \ln(y_{it}) - \ln(y_{i,t-T})] \} \\ / (1 + \varphi)^2 \text{var}[\ln(y_{i,t-T})],$$

and so cancelling like terms in equation (12) gives:

$$(13) \quad -\hat{\beta} = T^{-1} \text{cov}[\ln(y_{i,t-T}), \ln(y_{it}) - \ln(y_{i,t-T})] / \text{var}[\ln(y_{i,t-T})] = -\beta.$$

That is, in this case there is no bias to the estimated coefficient on initial income ($\hat{\beta}$) when using estimates of income derived from the monetary-based technique.

⁵ Note that $-\varphi = \partial \ln(V_{it}) / \partial \ln(y_{it}) = \partial \ln(Y_{it}/M_{it}) / \partial \ln(y_{it}) = \partial \ln(y_{it}) / \partial \ln(y_{it}) - \partial \ln(m_{it}) / \partial \ln(y_{it}) = 1 - \eta < 0$ for $\eta > 1$ (where $y_{it} = Y_{it}/L_{it}$, $m_{it} = M_{it}/L_{it}$ and η is the income elasticity of money demand in $m_{it} V_{it} = y_{it}$). Accordingly, $\varphi = -(1 - \eta) = (\eta - 1) > 0$ when $\eta > 1$.

⁶ Note that from (6) $\ln(\hat{y}_{it}) = \ln(y_{it}) + \ln(V_{at}) - \ln(V_{it})$, and so $\partial \ln(\hat{y}_{it}) / \partial \ln(y_{it}) = 1 + \varphi$, where $\varphi = -[\partial \ln(V_{it}) / \partial \ln(y_{it})]$ from $\ln(V_{it}) = -\varphi \ln(y_{it}) + \text{constant}$. Given that $\ln(V_{at})$ is constant across the colonies, then $\ln(\hat{y}_{it}) = (1 + \varphi)\ln(y_{it}) + \text{constant}$.

This occurs because the term $(1+\varphi)$ in $\ln(\hat{y}_{it}) = (1+\varphi)\ln(y_{it}) + \text{constant}$ enters both the left-hand and right-hand sides of the estimated regression equation, (9). Hence for constant proportional error in using the monetary-based technique, *all* initial incomes will be in error (scaled up by $(1+\varphi)$, for $\eta > 1$ and thus $\varphi > 0$) in all years, and my measure of $\hat{\beta}$ -convergence will be unbiased.

Note that if φ changed over time, say became larger, then $\ln(\hat{y}_{it})$ would be farther from the true $\ln(y_{it})$, and so a bias away from finding $\hat{\beta}$ -convergence would result. The similar case of $\varphi=0$ in the initial period, then $\varphi > 0$ in all subsequent periods, is discussed in Section 4.2 and Appendix B. Recent work by Mulligan and Sala-i-Martin (1992), however, demonstrates that after calculating year-by-year the cross-sectional estimate of η for the states of the United States, the hypothesis that η is stable over time cannot be rejected for the period 1929-1990. They find that not only is η constant (and hence φ is constant in the terminology of this paper), but also that $\eta > 1$.

4.2 Correct Estimate of $\ln(y_{i,t-T})$ and Errors in All Subsequent Periods

In this case, if the initial $\ln(\hat{y}_{i,t-T}) = \ln(y_{i,t-T})$ is the true value, and then subsequent values of $\ln(y_{it})$ are measured with error using the monetary-based technique, then the formula for the subsequent bias (see Appendix B for derivation) is:

$$(14) \text{ bias} = (-\hat{\beta}) - (-\beta) = T^{-1} \varphi \text{cov}[\ln(y_{i,t-T}), \ln(y_{it})] / \text{var}[\ln(y_{i,t-T})] = \varphi(T^{-1} - \beta).$$

Hence, for $\varphi > 0$ in (14) then if $T^{-1} > \beta$ the bias is positive (the biased $-\hat{\beta}$ is close to zero). That is, $(-\hat{\beta}) - (-\beta) > 0$ and so $-\beta < (-\hat{\beta})$ and the monetary-based technique will result in the underestimation of the speed of convergence ($\hat{\beta}$: the

coefficient on $\ln(y_{i,t-T})$). For small sample periods and given β is close to 0.02 (as estimated in other convergence studies mentioned above), then for T of less than about 50 years this bias will result. The opposite result will occur for $\eta < 1$ (money as an inferior good) and $T^{-1} > \beta$, as then $\varphi < 0$ in (14) and the bias is negative (that is, $-\hat{\beta}$ is overestimated and is further away from zero).

The arguments contained in Section 6.2 of Cashin (1993a), principally those of Fisher (1911), Friedman (1959), Tobin (1965), Bordo and Jonung (1981) and, more recently, work by Mulligan and Sala-i-Martin (1992), all describe a tendency for less-developed economies to have higher income velocities of money, that is for money to be a luxury good ($\eta > 1$). Cagan (1965) and McKinnon (1973) also present evidence of falling V through time and across countries as national income rises. Hence in this case for $\eta > 1$, $-\hat{\beta}$ in equation (14) would be underestimated and consequently biased toward zero.

5. Analysis of σ -Convergence Across the Colonies

In examining the extent of σ -convergence across the seven Australasian regions I calculate the unweighted cross-sectional standard deviation of $\ln(y_{it})$, σ_t , from 1860-1991. Figure 5 shows a secular downward trend for the dispersion of real per capita GDP among the Australian colonies, save for the periods 1861-1871, 1901-1921 and 1947-1951. The dispersion (σ_t) declined from 0.341 in 1860 to 0.107 in 1901, but then rose to 0.162 by 1921. It then falls again to 0.103 by 1947, and subsequently rises to 0.136 in 1951, before continuing its fall to 0.101 in 1991. An OLS regression of σ_t on a time trend and a constant term revealed that for the 1861-1991 period the coefficient on the time trend was significantly negative ($\hat{\beta} = -0.0015$ [$t = -5.381$]). For the 1861-1901 period the coefficient was even larger ($\hat{\beta} = -0.0061$ [$t = -6.483$]). Similarly, for the 1921-1991 period, (where

σ_t resumed its downward path after the 1901–1921 divergence period), the coefficient is significantly negative ($\hat{\beta} = -0.00079$ [$t = -4.715$]), yet lower than for the 1861–1901 period.

This process of a reduction in the cross-sectional dispersion of per-capita GDP for the Australian states is very similar to the pattern exhibited by Japan and the United States, where the minimum value of σ was found to be 0.12 and 0.14, respectively (Barro and Sala-i-Martin 1992, 1992a). An important difference is that, although the minimum value for the latter two countries was reached in the mid-1970s and has since risen, for Australia the decline in σ_t has basically plateaued at about 0.11 since the early 1970s, yet has not subsequently risen.

The pattern of Australasian σ -convergence with NZ included (Figure 6) is close to that of Australian σ -convergence without NZ (Figure 5), except for additional divergence periods between 1954–1961 and 1981–1986. The former period can be largely explained by the sustained high level of NZ's terms of trade (TOT) until the late 1950s, while the Australian TOT had returned to its pre-Korean War levels by the early 1950s (Connor and Easton 1980). Conversely, the latter period's σ -divergence is primarily due to the relatively poor growth performance of NZ during most of the 1980s, when compared with the Australian states. These periods of σ -divergence will be analysed in greater detail in Section 7 below.

A useful disaggregation of the data is to examine whether the initially-rich economies in 1861 (VIC and NSW), experienced σ -convergence as a sub-group, and whether the initially-poor economies (WA and SA) did likewise. The results reveal that indeed σ -convergence applies to the rich colonies (VIC and NSW: σ_t fell from 0.049 in 1861 to 0.005 in 1901, and rose slightly to 0.007 in 1991) and also

to the poor colonies (WA and SA: σ_t fell from 0.162 in 1861, to 0.077 in 1901, and rose slightly to 0.082 in 1991).

The path of the logarithm of real per-capita GDP for the six Australian colonies (excluding NZ) from 1850–1991 (in 1910–1911 Australian dollars (A\$)) is plotted in Figure 7. A clear indication that the average per-capita GDP levels in each colony are becoming more similar over time is revealed. The non-eastern states (WA, TAS and SA) are shown to become more like their traditionally more important (mainland) counterparts (NSW, VIC and QLD). A similar result is found in Figure 8, where real per-capita GDP for 1861–1991 for NZ and the eastern colonies of NSW, VIC, QLD and TAS is plotted. My results in Figure 7 can be compared with the (very similar) ranking over time of state taxable capacities (tax effort) of Giblin (1926), given in Appendix E of Cashin (1993).

6. Implications for σ -Convergence of Measurement Error in the Monetary-Based Estimates of GDP

For the case where $\ln(y_{it})$ is measured with error V_t , then as noted in Section 4 for constant φ the estimates of β -convergence will not be biased, as both the right-hand and left-hand sides of equation (9) will be scaled up by the same term, $(1+\varphi)$. However, the calculated $\hat{\sigma}$ -convergence will be overestimated, that is, the shrinkage of the dispersion of per-capita incomes across the colonies will appear more rapid than it is in reality, as $\hat{\sigma}_t$ is scaled up (for $\varphi > 0$) by this same term $(1+\varphi)$, entering here multiplicatively (see equation (17) below). The bias here acts to magnify any given σ -convergence or σ -divergence. Although the cross-sectional dispersion will be measured with error, it should be noted that $\hat{\sigma}_t$ will always have the direction of movement in σ_t correct: if σ_t is falling (σ -convergence) then $\hat{\sigma}_t$ will also be falling; if σ_t is rising (σ -divergence) then $\hat{\sigma}_t$

will also be rising; and if σ_t is constant, then $\hat{\sigma}_t$ will also be constant. These results are derived below.

The variance of $\ln(\hat{y}_{it})$ is, using equation (6):

$$(15) \quad \hat{\sigma}_t^2 = \text{var}[\ln(\hat{y}_{it})] = \text{var}[\ln(y_{it}) + \ln(V_{at}) - \ln(V_{it})],$$

and so for $\ln(V_{at})$ constant across the colonies then:

$$(16) \quad \hat{\sigma}_t^2 = \text{var}[\ln(\hat{y}_{it})] = \text{var}[\ln(y_{it}) - \ln(V_{it})],$$

and given that $\ln(y_{it}) - \ln(V_{it}) = (1+\varphi)\ln(y_{it}) + \text{constant}$, as suggested in Section 4, then (16) becomes:

$$(17) \quad \hat{\sigma}_t^2 = \text{var}[(1+\varphi)\ln(y_{it})] = (1+\varphi)^2 \text{var}[\ln(y_{it})] = (1+\varphi)^2 \sigma_t^2,$$

and so $\hat{\sigma}_t = (1+\varphi)\sigma_t$ ⁷. For $\eta > 1$ (money as a luxury good) and so $\varphi = -(1-\eta) > 0$, if there is actual convergence (with σ_t falling to its steady state value, σ), then the estimated $\hat{\sigma}$ -convergence will appear more rapid than the true σ -convergence. That is, the slope of the $\hat{\sigma}_t$ line will be greater than the slope of the σ_t line, with the $\hat{\sigma}_t$ line above the σ_t line. Hence, the monetary-based method will result in an

⁷ Note that another way to derive this result is the following. The true regression is given by (7), and the erroneous actual regression is given by (8). Hence if

$\ln(\hat{y}_{it}) = (1+\varphi)\ln(y_{it}) + \text{constant}$, as argued above, then (8) becomes:

$T^{-1}(1+\varphi)[\ln(y_{it}) - \ln(y_{i,t-T})] = \hat{\alpha} - \hat{\beta}(1+\varphi)\ln(y_{i,t-T}) + \hat{\epsilon}_{it}$, and so dividing through

by $(1+\varphi)$ gives: $\beta = \hat{\beta}$ and $\epsilon_t = \hat{\epsilon}_t / (1+\varphi)$. Barro and Sala-i-Martin (1992) show

that in the steady state $\sigma^2 = \sigma_\epsilon^2 / (1 - e^{-2\beta})$, and so here we get the result that:

$\hat{\sigma}_t^2 = \sigma_\epsilon^2 = \sigma^2 (1+\varphi)^2 / (1 - e^{-2\beta}) = (1+\varphi)^2 \sigma^2$, as derived in equation (17) above.

overestimation of σ -convergence if $\ln(y_{it})$ is measured with constant proportional error in all periods, including the initial period. Note again that if there truly is no σ -convergence, then the estimated $\hat{\sigma}$ -convergence will also correctly show no change in the dispersion of cross-colony per-capita incomes.

For the case where initial $\ln(y_{i,t-T})$ is the true value, and then the monetary-based technique is used to estimate (with error) subsequent $\ln(y_{it})$, then for $\eta > 1$ there will be erroneous $\hat{\sigma}$ -divergence (when there truly is no convergence) and underestimation of σ -convergence (when there truly is σ -convergence). This occurs because initially $\sigma_{t-T} = \hat{\sigma}_{t-T}$ as our income estimates are measured without error for period $t-T$. With subsequent incomes ($\ln(\hat{y}_{it})$) measured with error, then $\hat{\sigma}_t$ will be biased upward and so the slope of $\hat{\sigma}_t$ will be flatter than the true σ_t , and accordingly σ -convergence will be underestimated. Further details are given in Appendix B.

A summary of the key cases follows, where all cases assume a constant proportional error (constant φ) from use of the monetary-based technique. When initial period income, $\ln(y_{i,t-T})$, is measured correctly and all subsequent $\ln(y_{it})$ are measured with error due to use of the monetary-based technique, then the monetary-based technique will tend to underestimate both β - and σ -convergence (for growing economies) for $\eta > 1$ and overestimate both types of convergence for $\eta < 1$.

In the case of most relevance here, where $\ln(y_{it})$ in all periods (including the initial period) is measured with error by using the monetary-based technique, then for $\eta > 1$ (money as a luxury good) and $(1+\varphi)$ constant there will be no bias imparted on the speed of estimated $\hat{\beta}$ -convergence, while the estimated $\hat{\sigma}$ -convergence will overestimate the true σ -convergence. For $\eta < 1$ (money as an inferior good) and $(1+\varphi)$ constant there will again be no bias in $\hat{\beta}$ -convergence, while $\hat{\sigma}$ -convergence will underestimate the true σ -convergence.

Given that for most of the period of analysis the Australian income velocity of money was falling, which is indicative of $\eta > 1$ (as argued in Section 6.2 of Cashin (1993a)), then for the present study there will be an overestimation of cross-colony σ -convergence arising from use of the monetary-based technique to estimate per-capita colonial incomes in all periods. That is, given the above assumptions then any pattern of diminishing cross-colony dispersion of per-capita incomes will be a combination of *true* σ -convergence and *artificial* σ -convergence arising from use of the monetary-based data. The influence of the artificial component could thus partly account for the observed rapid $\hat{\sigma}$ -convergence of the colonies in the 1861–1901 period. A similar combination of (true and artificial) influences would also exist for any observed pattern of σ -divergence. Of course, it should be noted that after 1933 (for NZ) and after 1979 (for the Australian states), official estimates of economy per-capita incomes are used in this analysis.

7. The Divergence Periods⁸: 1861–1871, 1900–1911, 1911–1921 and 1947–1951

From Figures 5 and 6 it is clear that the secular trend of decline in σ_t for the economies of Australasia breaks down in three periods, when σ -divergence occurs as the real per-capita incomes of the economies became less similar: 1861–1871, 1900–1921 and 1947–1951. Gold was the catalyst for divergence in the first sub-period, as the initially-rich economies in 1861 (VIC, NSW and NZ) also

⁸ Increases in the cross-economy dispersion of the logarithm of real per-capita incomes are often induced by a positive correlation between exogenous movements in relative prices and initial income. That is, if an initially-poor, agricultural-based colony j experiences an exogenous fall in the relative prices of its agricultural goods, then $\mu_{jt} \neq \mu_{it}$ in (2), for colony $i \neq$ colony j , and so such shocks can result in σ_t diverging from σ .

turned out to be those blessed with abundant gold reserves which were exploited in the subsequent decade, raising their growth rates.

Closer examination of the 1901-21 period in Figure 9 reveals a two-tier result, with TAS, NZ, QLD and WA on the low tier, and NSW, VIC and SA on the high tier. Such a result is indicative of a (for example, technological or TOT) shock which adversely affects *all* subgroups of regions (such as agriculture-based colonies), be they initially poor, such as TAS, or initially rich, such as WA or QLD. Indeed computation of σ_t for the four low-tier colonies reveals that it decreased from 0.098 in 1901 to 0.075 in 1921, and for the three high-tier colonies σ_t decreased from 0.095 in 1901 to 0.041 in 1921. Hence there is σ -convergence across the high-tier colonies, and across the low-tier colonies, with exogenous fiscal, trade and TOT shocks acting to separate the two groups. Wool is the catalyst for divergence in the final sub-period, as a favourable TOT shock occurred between 1947-1951, with the initially-rich economies (VIC, NSW, SA and NZ) growing relatively faster with a boom in the prices for their major pastoral-based (wool) exports. Each of the above periods will now be examined in more detail.

7.1 [1861-1871] VIC and NZ: Gold Abundance and Gold Deprivation

Although data on the Australian TOT are unavailable prior to 1871, NZ's TOT reveals 1871 (and more generally the latter half of the 1860s) to be the low-point in the 1861-1991 lifetime of the index (Simkin 1951, Connor and Easton 1980). Accordingly, those colonies with large import-competing sectors would be expected to do relatively well in this decade. This is certainly borne out in the

data (Figure 10), but in addition those colonies with abundant, cheaply-recovered gold reserves were able to prosper relative to those without such resources⁹.

Given the close relationship (documented by Connor and Easton 1980) between the NZ TOT and its Australian counterpart (see Figure 11) in the 1871-1960 period, it is reasonable to assume a similar collapse in the Australian TOT during the 1860s. Data from Coghlan (1904) and McIlraith (1913) reveal that this was most likely due to import prices rising faster than export prices. As such, Figure 10 reveals that those colonies with negligible gold production and/or small import-competing sectors (WA and TAS) were below-average growth performers (and (for WA) began from a relatively low level of per-capita GDP), whilst those with the opposite attributes (VIC and NZ) grew relatively rapidly from an already high (for VIC due largely to gold extraction in the 1850s; for NZ due to its highly-productive wool industry) level of real GDP per capita. Holding constant the impact of gold production, convergence applies to the 'gold-abundant' (VIC and NZ: σ_t reduced from 0.110 to 0.068) and 'gold-deprived' (WA and TAS: σ_t reduced from 0.324 to 0.227) economies as separate groups over this 1861-1871 period¹⁰.

⁹ Coghlan's (1904, p.921) data for this decade reveals that of the A\$216.924m (£108.462m) gross value of gold production in Australasia, some 62 per cent was extracted in VIC, 14 per cent in NSW, 22 per cent in NZ and 2 per cent in QLD. By comparison, Australia's nominal GDP for 1851 was A\$27.41m, 1861 was A\$133.6m and for 1871 was A\$166.0m (Butlin 1962). Known gold reserves in WA, SA, and TAS were negligible at this time, although in the 1890s and early 1900s gold production in WA and QLD boomed. By the early 1870s wool had supplanted gold and regained its position as the continent's major export commodity.

¹⁰ The consequences for VIC, NSW and NZ of the exploitation of their large gold reserves in the 1850s and 1860s have been examined by Maddock and McLean (1984), Condliffe (1915), Simkin (1951) and Hawke (1985), among others. It can also be argued that NZ's relative position would have been further enhanced in the absence of its expensive Maori Wars of the 1860s.

7.2 [1901–1911] TAS: Capital Flight and Loss of Inter-State Trade Barriers

For the 1901–1911 period TAS is the definite outlier (see Figure 12), and is largely responsible for the slow speed of $\hat{\beta}$ -convergence in this decade. Its relatively poor growth performance can be partly explained by the fiscal consequences arising from the loss of its customs and excise tax base following Federation of the Australian colonies in 1901. As a result of Federation, trade barriers within the customs union were terminated, and external barriers set at near the rate of the more protectionist of the ex-colonies. The loss of the ability to levy customs duties against the exports of other ex-colonies differentially disadvantaged TAS, as the loss of protection and lack of economies of scale caused its relative share of Australia's capital stock to fall. The common external tariff, a key outcome of Federation, obviously benefitted the industrial (import-competing) states of VIC, QLD and NSW at the expense of agricultural (export-oriented) states like WA and (to a lesser extent) TAS¹¹. In the decade 1901–1910 WA was compensated by the Commonwealth Government for these tariff-induced effects, whilst TAS was not.

While all ex-colonies (except NZ) were deprived of direct access to customs revenue after 1901, TAS suffered relatively more as a result, given that its small population and lack of natural resources afforded it fewer alternative tax bases. Table 3 reveals the extent of this lost revenue, as well as the relatively large share of total revenue contributed by customs and excise duties in TAS. Although the Federation agreement contained a clause which gave back to all the new states up

¹¹ While the case for WA net losses under a common (relatively high) external tariff is clear, TAS did reap some advantages from the tariff in that its own manufacturing industries were sheltered from foreign competition. However, soon after Federation the inability to attain economies of scale and geographical disadvantages of TAS production resulted in the shrinkage of manufacturing's share of Tasmanian GDP.

to three-quarters of all federally-gathered customs and excise revenue for 10 years (1901-10), the TAS tax base was severely eroded in this, Australia's first decade.

Moreover, in the 1890s and the first two decades of this century TAS spent relatively more than the colonial average on investment in public infrastructure (primarily roads, bridges and railways). However, this increase in (unfortunately, often unproductive) capital expenditure did not coincide with cuts in other public spending; was only partly met by increases in current revenue; and consequently was largely met (particularly in the 1901-10 period) by raising loans both within Australia and on foreign capital markets. The payment of interest on this essentially unproductive debt hastened the arrival of TAS' fiscal problems (Piesse 1930).

Due to its relatively small share of revenue derived from public works and services, and despite its relatively large share of assistance received through Federal transfers (see Table 4), TAS was obliged to resort to a much larger extent to contemporaneous taxation (especially direct (often income) taxation, see Tables 5-7) and borrowing (future taxation) than the other states. Such a high-taxing government can be viewed as one which lowers the level of technology, A , in production functions like $y(t)=Ak(t)^{12}$ - thus contributing to TAS' lower rate of growth. The TAS gross state debt as a share of GDP subsequently rose rapidly from a relatively low base (see Table 8), and by 1905 (and until about 1915) TAS revenue from all taxation was insufficient to cover the interest on its state debt (Robson 1991)¹³.

¹² Where y and k are per-capita production and capital, respectively.

¹³ TAS' parlous situation in the 1901-1910 decade was indeed ironic in that it had been an early and strong proponent for the formation of a customs union among the Australasian colonies, based largely on the discouragement given to its exports by high tariffs put in place by the mainland colonies, particularly in the 1860s and 1870s (Patterson 1968).

However, given that there were no barriers to flows of capital and labour between the states, economic agents would have an incentive to avoid such relatively high (source-based) state income taxes. They would optimally choose to move their labour (that is, themselves) and/or their capital interstate (or overseas), to take advantage of relatively lower source-based income taxes in other states. A source-based tax on capital income (acting as a tax on investment) will raise the gross return to domestic capital through a reduction in the quantity of domestically-located capital. As a result, the TAS economy would have suffered a welfare loss, foregone investment, and consequently a lower rate of economic growth.

Figures 13 and 14 offer some tentative evidence that private savings were partly transferred to other (lower income-taxing) states, thus lowering TAS' (physical and human) capital stock, and accordingly its rate of economic growth. Figure 13 reveals that TAS' share of Australian value added in manufacturing fell permanently from 1898, in comparison with earlier years. Figure 14 also clearly demonstrates the rapid and permanent fall in TAS' share of Australian employment in manufacturing after 1901. Both of the above are also, of course, consistent with *ex-ante* predictions given the withdrawal in 1901 of trade barriers to manufacturing imports into TAS from other Australian states.

7.3 [1911-1921] WA and NZ: Adverse Terms of Trade (TOT) Shocks

A temporary fall in the (net barter) TOT should result in minimal wealth effects, and most of the response of forward-looking agents should appear as substitution effects. If we assume that all goods in each of the state economies are traded, then lower work effort and a corresponding fall in the supply of domestic goods should result from a temporary fall in the TOT, with a small diminution in

consumer demand and lower desired savings (as consumers optimally choose to intertemporally smooth their consumption paths). There would be little effect on investment demand (although investment could fall if the duration of the 'temporary' adverse TOT shock lengthens). Lower private saving would in turn induce lower growth rates, in the absence of higher public saving (Sachs 1981, Svensson and Razin 1983)¹⁴.

Figure 15 reveals that WA and NZ were the poor-performing economic outliers of the period 1911-1921. The decade of 1911-21 is of course marked by the First World War, 1914-1918, which at first glance proved to be a quite prosperous five years for the ex-colonies, given British contracts for the supply of agricultural and mineral commodities at relatively high prices (Hawke 1985). However, the TOT data for Australia (see Figure 11) reveal that although export prices were rising, the War also induced much higher import prices, leading to a steady fall in the TOT between 1913 and 1922, so that in 1922 it was some 25 per cent below its level in 1901¹⁵. After 1922 the TOT rose rapidly to exceed its previous highs¹⁶. The story for NZ is similar to that for Australia, except for the rapid rise in their TOT from 1902 to a peak at 1905, and then a fall back to its

¹⁴ Moreover, in the presence of nontradeables a fall in the TOT motivates the home country to shift production, employment and investment away from the tradeables sector and into nontradeables. At the same time, those regions of the Australasian economy with a relatively large share of tradeables production (WA and NZ) would be expected to suffer relatively more of the above consequences than those with a relatively smaller share (NSW, VIC, QLD and TAS). See Salter (1959) and Swan (1960) for the original exposition of the Australian (or dependent economy) model.

¹⁵ Hawke (1985, p.99) attributes the post-War collapse in the TOT to: greater competition in the British market for foodstuffs (which dampened rises in the export prices of meat, dairy and wool products); a slowdown in the rate of productivity gains in the agricultural sectors of both Australia and NZ; and higher prices for importables from Britain.

¹⁶ Between 1910-1922 Australian exports had an average value of A\$ 201.32m, while for imports the corresponding figure was A\$ 227.89m (Vamplew 1987). Hence the large fall in the net barter TOT was only partially offset by rising net export volumes.

1901 level by 1910. NZ generally also experienced the TOT fall during the immediate War years, and the rapid post-War rise (Connor and Easton 1980).

These wartime experiences, reflected in the divergence of σ_t in Figures 5 and 6, hit the agriculture-dependent and external trade-dependent states (WA and NZ) relatively harder than other Australasian economies. Accordingly, the decade 1901–11 was relatively prosperous for NZ, while the 1911–21 period had a detrimental effect on both NZ and WA, given the adverse TOT shocks upon their relatively trade-dependent economies. An indication of the greater trade-dependence of these two colonies during 1883–1909 is given in Table 9.

Note that from Figure 11, product prices (as measured by the GDP deflator) have average growth rates over the 1870–1950 period similar to those for the ratio of import to export prices, although the former is much smoother. Product prices rose much faster than the prices of traded goods during the 1901–1921 period, which suggests that the prices of nontradeables rose more quickly than those for tradeables. Again, this would tend to benefit those colonies with economies specialising in the production of (internationally) nontradeable goods, such as NSW, VIC and QLD, and harm those economies which were more trade- and agriculture-dependent, such as NZ and WA.

In summary, a temporary adverse shock to the TOT would detrimentally affect economies relatively more dependent on (internationally) tradeable goods (WA and NZ), whilst benefiting those economies relatively more dependent on nontradeable goods (NSW, VIC, SA, QLD and TAS). This would be expected to reduce private savings and thus relative growth rates in the former economies. Note that holding constant the impact of the TOT shock, σ -convergence applies to the 'non-external trade dependent' economies (NSW, VIC, QLD, SA and TAS: σ_t reduced from 0.172 to 0.158) economies, but there is almost no change for the

'external trade dependent' economies (NZ and WA: σ_t increased from 0.016 to 0.017) during the 1911–1921 period.

7.4 [1947–1951] NZ, VIC and NSW: Wool and the Korean War

As was the case following the First World War, the TOT for Australia and NZ recovered and rose above their pre-Second World War levels during the 1947–1951 period, but on this occasion reached record highs for both countries in 1951, primarily due to the spurt in world demand for commodities provided by the Korean War (see Figure 11). Wool was the commodity largely fueling the rise in export prices, although world prices of grains (particularly wheat) also rose rapidly during this period.

Given the above scenario, those Australasian economies specialising in wool production would be expected to do relatively well in this period¹⁷. Although Figure 16 reveals that the 1947–1951 period is one of rapid growth for most of the economies, for NZ it is one of *extremely* rapid growth from the highest (in 1947) per-capita GDP level of all the colonies, with VIC, NSW and SA (the latter two from lower initial GDP levels) also performing relatively well. The positive correlation between initial income and subsequent growth revealed in Figure 16 is largely driven by the rise in income of wool-rich NZ, which induces $\hat{\beta}$ -divergence

¹⁷ An approximate indication of the relative contribution of wool production for each of the colonies can be obtained from each colony's share of total Australasian wool production, and each colony's gross value of wool production as a share of its GDP. Of the average aggregate Australasian production of wool between 1947–1951 of 651.2m kg, some 32.59 per cent was produced in NSW, with the corresponding percentages for the other states being 26.19 for NZ, 14.54 for VIC, 7.94 for SA, 13.16 for QLD, 6.80 for WA and 1.14 for TAS. The average gross value of wool production (between 1949–1951) as a share of each economy's GDP in 1951 was: 12.43 for NSW, 3.79 for VIC, 12.55 for QLD, 11.98 for SA, 17.20 for WA, 7.22 for TAS and 11.55 for NZ (see CBCS 1955, p.731; Department of Statistics 1957, p.450; author's calculations).

across the colonies over this sub-period. As would be expected, economies such as WA, TAS and QLD which were not relatively specialised in wool production (although largely agricultural-based economies) performed relatively poorly, and had commenced the period with relatively low per-capita GDP levels. That is, the exogenous movement in relative prices was positively correlated with initial income, increasing the cross-state dispersion of real per-capita income for any given shock. Note that holding constant the impact of the TOT shock, σ -convergence applies to the 'non-wool' economies (WA, TAS, QLD: σ_t reduced from 0.062 to 0.037) economies, but not the 'wool' economies (NZ, VIC, NSW and SA: σ_t increased from 0.081 to 0.135) during the 1947–1951 period. The latter result comes about due to the particularly strong relative boost received by NZ due to its greater specialisation in wool production (even when compared with the other 'wool' economies).

8. Conclusion

Using monetary-based data constructed in Cashin (1993, 1993a), strong evidence has been brought forward for the existence of convergence in real per-capita GDP across the colonial economies of Australasia during the period 1861–1991. The speed at which the initially-poor colonies have caught up to the initially-rich colonies is similar to those obtained in analyses of regional convergence in the United States, Europe and Japan.

Although cross-colony convergence appears here, when the income elasticity of money demand is greater than one and a constant proportional measurement error exists in the estimated incomes for all periods, then there is a tendency for the monetary-based data (as an approximation to the true levels of real colonial per-capita GDP) to overestimate the extent of σ -convergence. It is important to

note that while the cross-sectional dispersion will most likely be measured with error, $\hat{\sigma}_t$ will always correctly track the direction of movement in σ_t . Further, given that the use of monetary-based data imparts a constant proportional measurement error to calculations of real per-capita colonial incomes in all periods, then the speed of $\hat{\beta}$ -convergence will be unbiased.

Over the long sample period of 1861-1991, the estimated β -coefficient is 0.0274 for Australasia (Australia and New Zealand), holding constant a measure of the differential sectoral composition across the colonies. That is, given similar steady states across the colonies, some 2.74 per cent of the gap between any colony's initial level of per-capita income and its steady-state level of per-capita income is closed every year, implying that it has historically taken about 25 years for half of any gap in real per-capita incomes between the poor colonies and the rich colonies to be eliminated.

There has also been a diminution of the standard deviation of the logarithm of real per-capita GDP (σ -convergence) across the colonies. However, there are several periods of σ -divergence when either the initially-rich colonies became richer or the initially-poor colonies became poorer, due to various relative price, endowment or fiscal shocks. This process of σ -convergence appears to be continuing even as late as 1991, although at levels of dispersion of per-capita incomes which are very close to those which were initially attained as early as 1901.

Fig 1 Real Per-Capita GDP
1970 US\$, 1860-1979

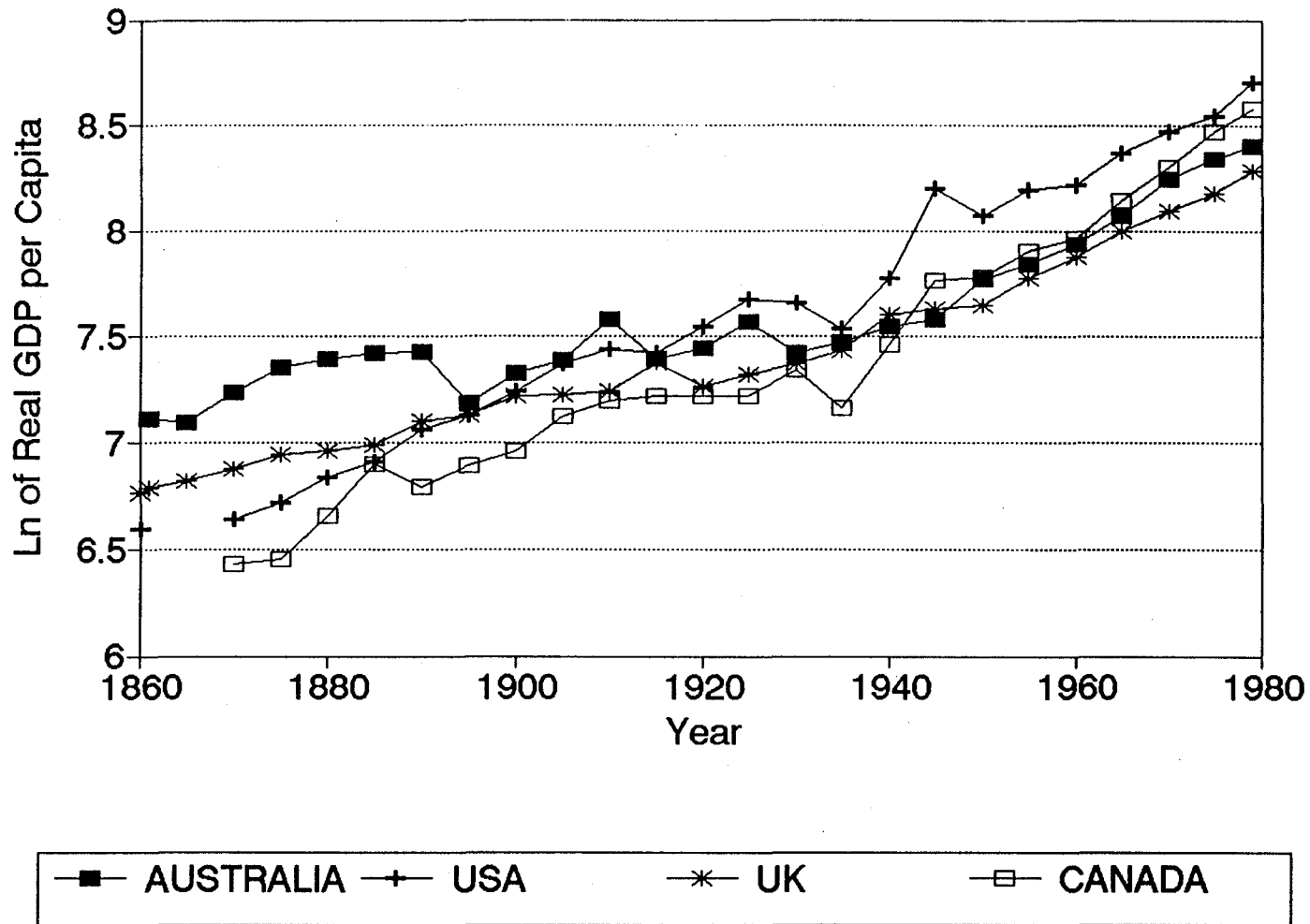


Fig 2 Convergence of Real Per-Capita
GDP: 1861 GDP and GDP Growth 1861-1991

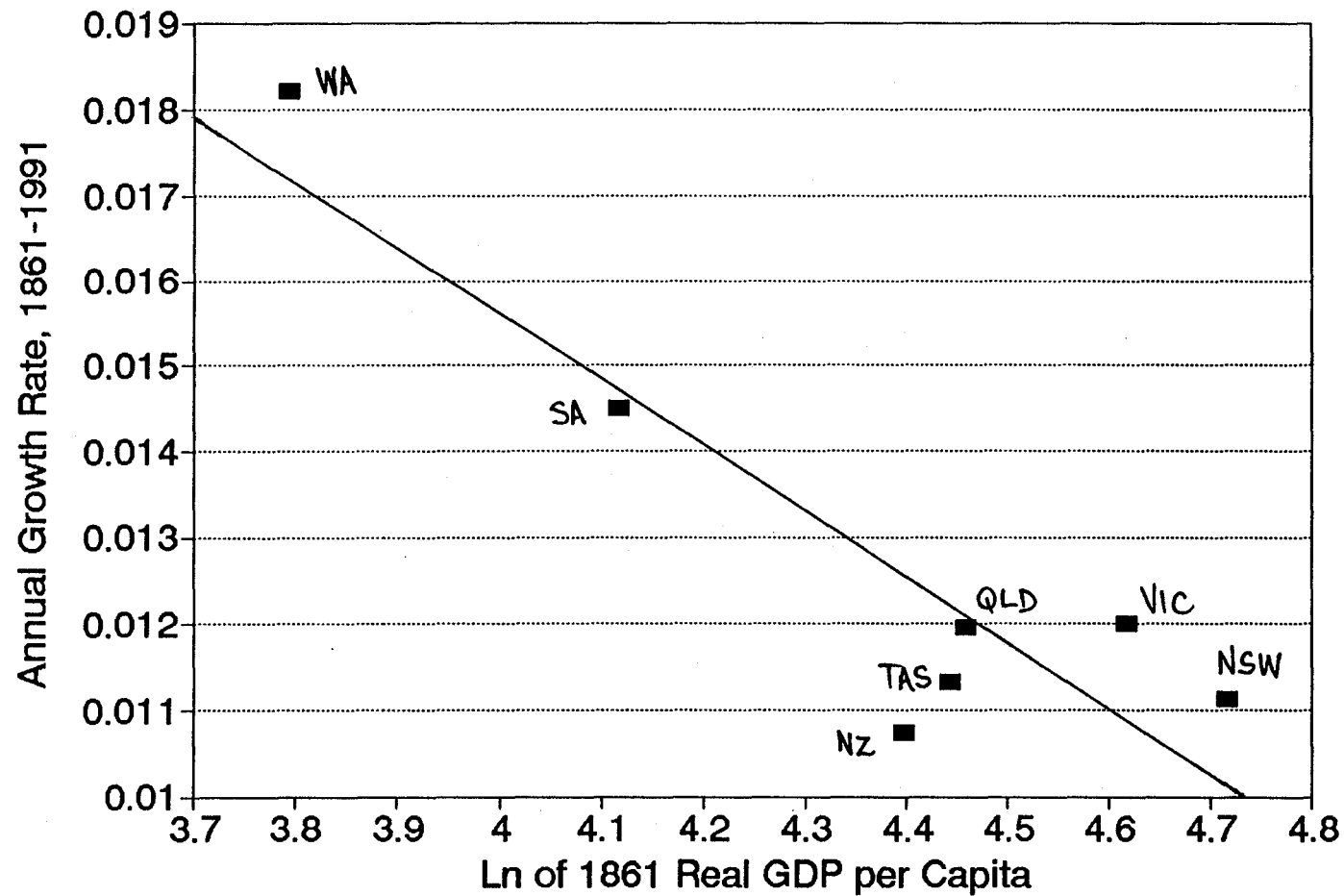


Fig 3 Convergence of Real Per-Capita
GDP: 1861 GDP and GDP Growth 1861-1901

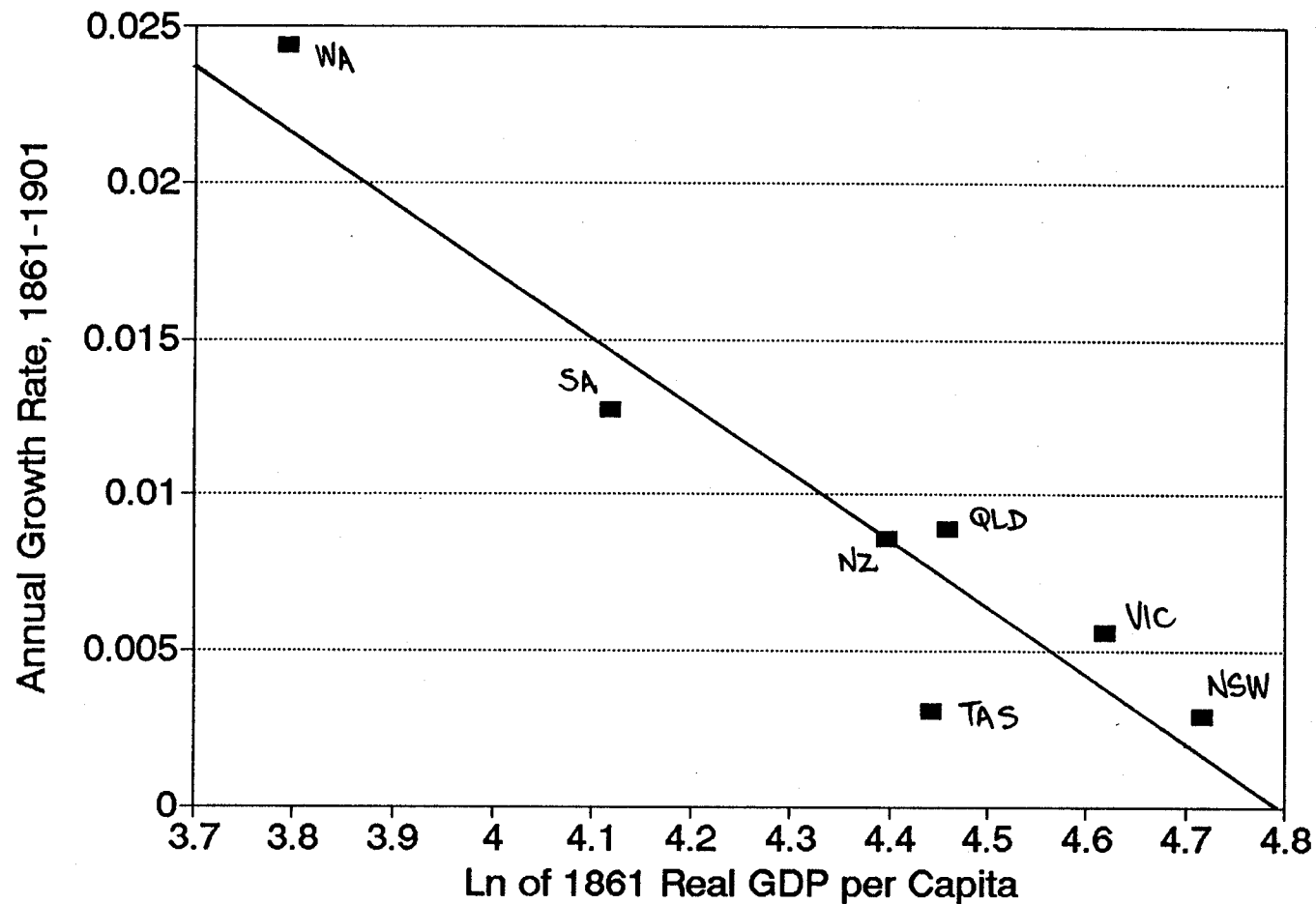


Fig 4 Convergence of Real Per-Capita
GDP: 1901 GDP and GDP Growth 1901-91

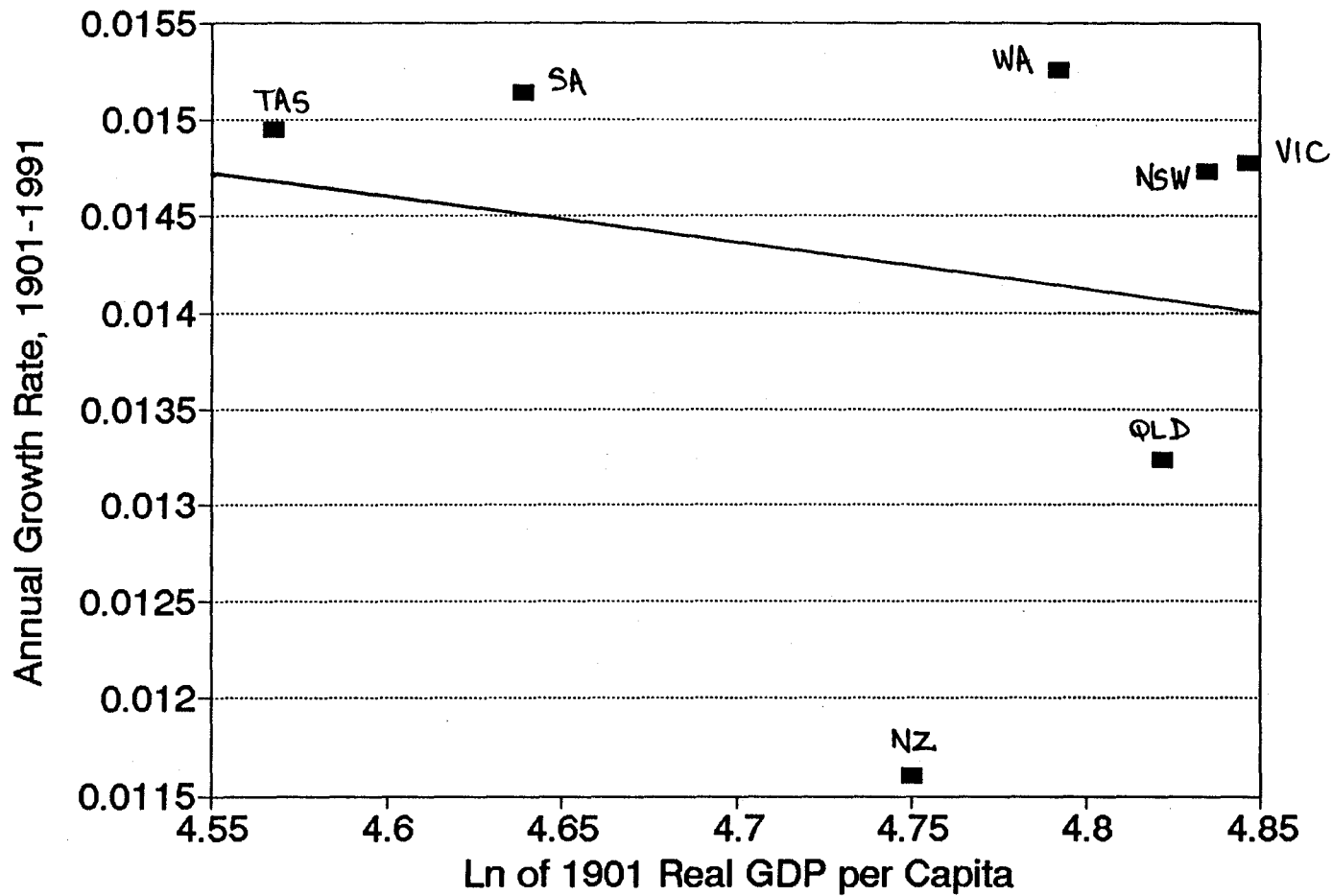


Fig 5 Dispersion of Per-Capita GDP
Australian Colonies, 1860-1991

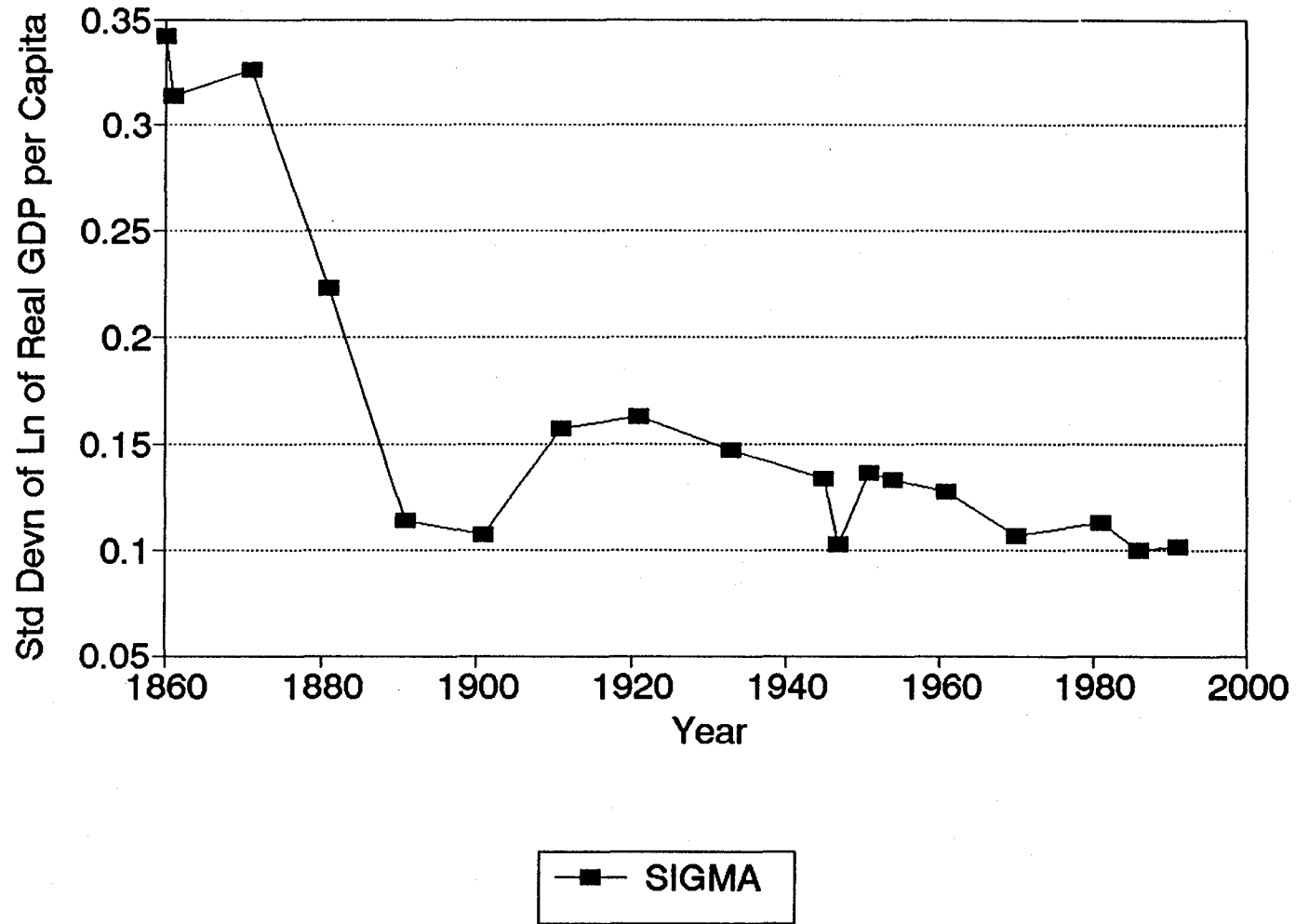


Fig 6 Dispersion of Per-Capita GDP
Australasian Colonies, 1861-1991

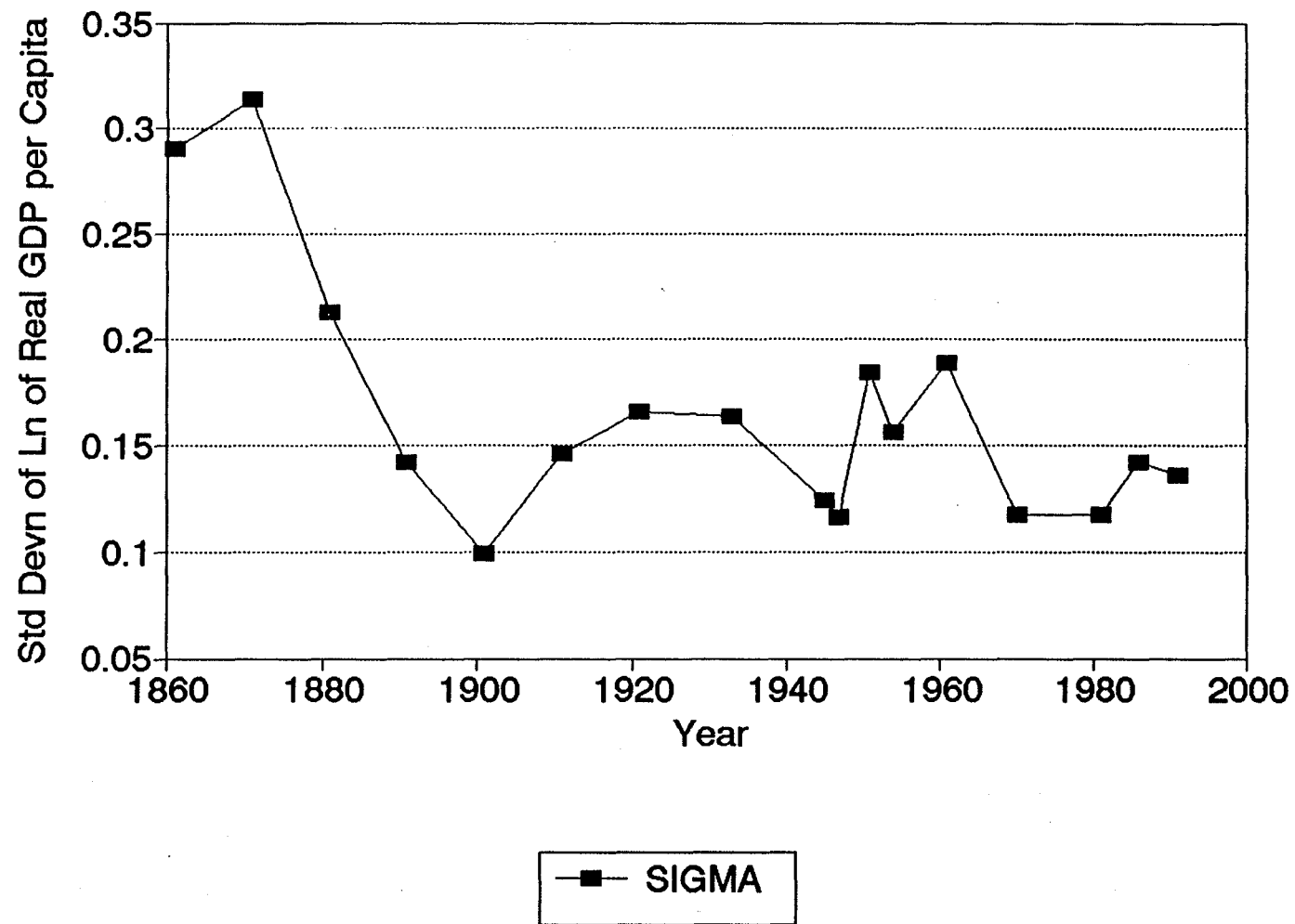


Fig 7 Real Per-Capita GDP, Australian Colonies, 1911 \$A, 1850-1991

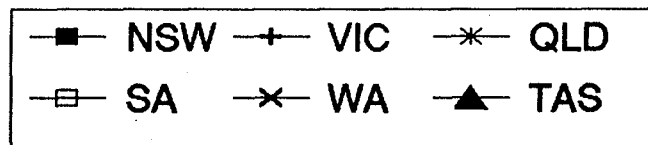
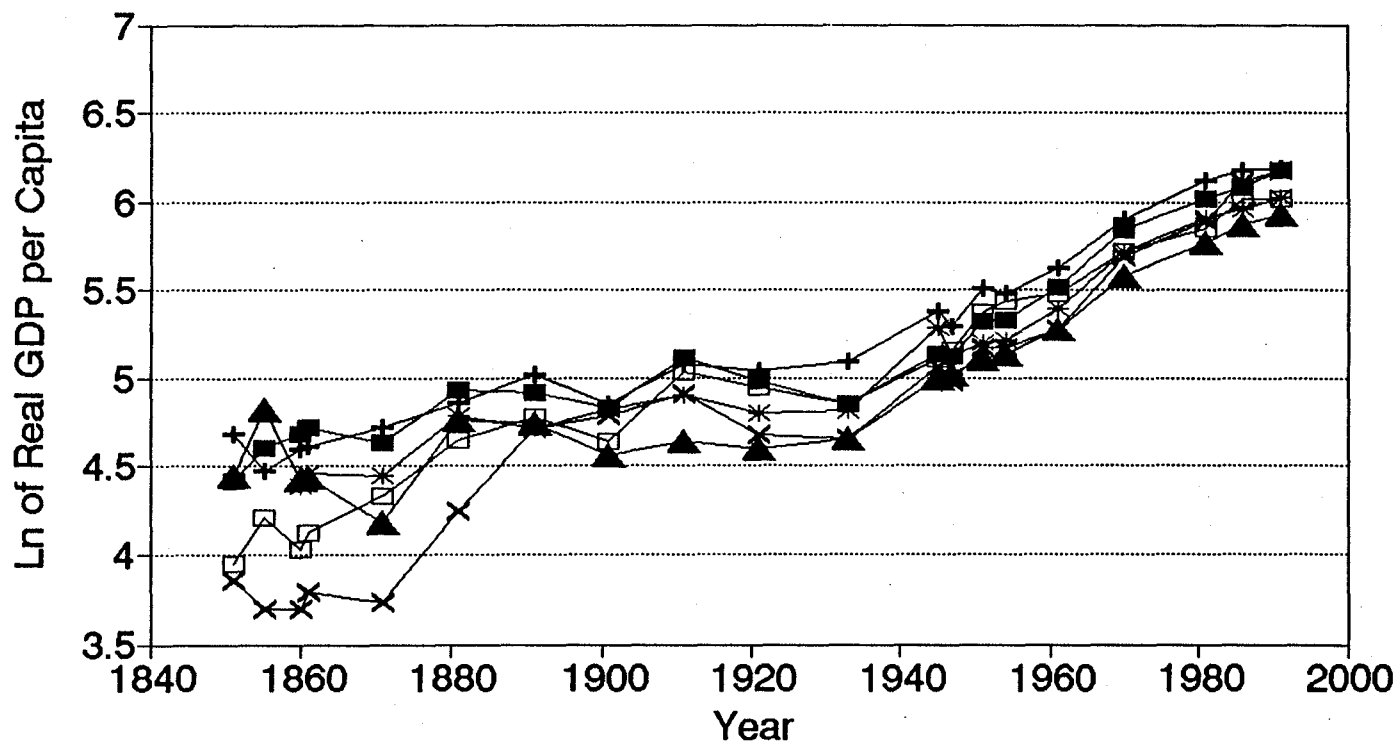


Fig 8 Real Per-Capita GDP, NZ and Four East Colonies, 1911 \$A, PPP, 1861-1991

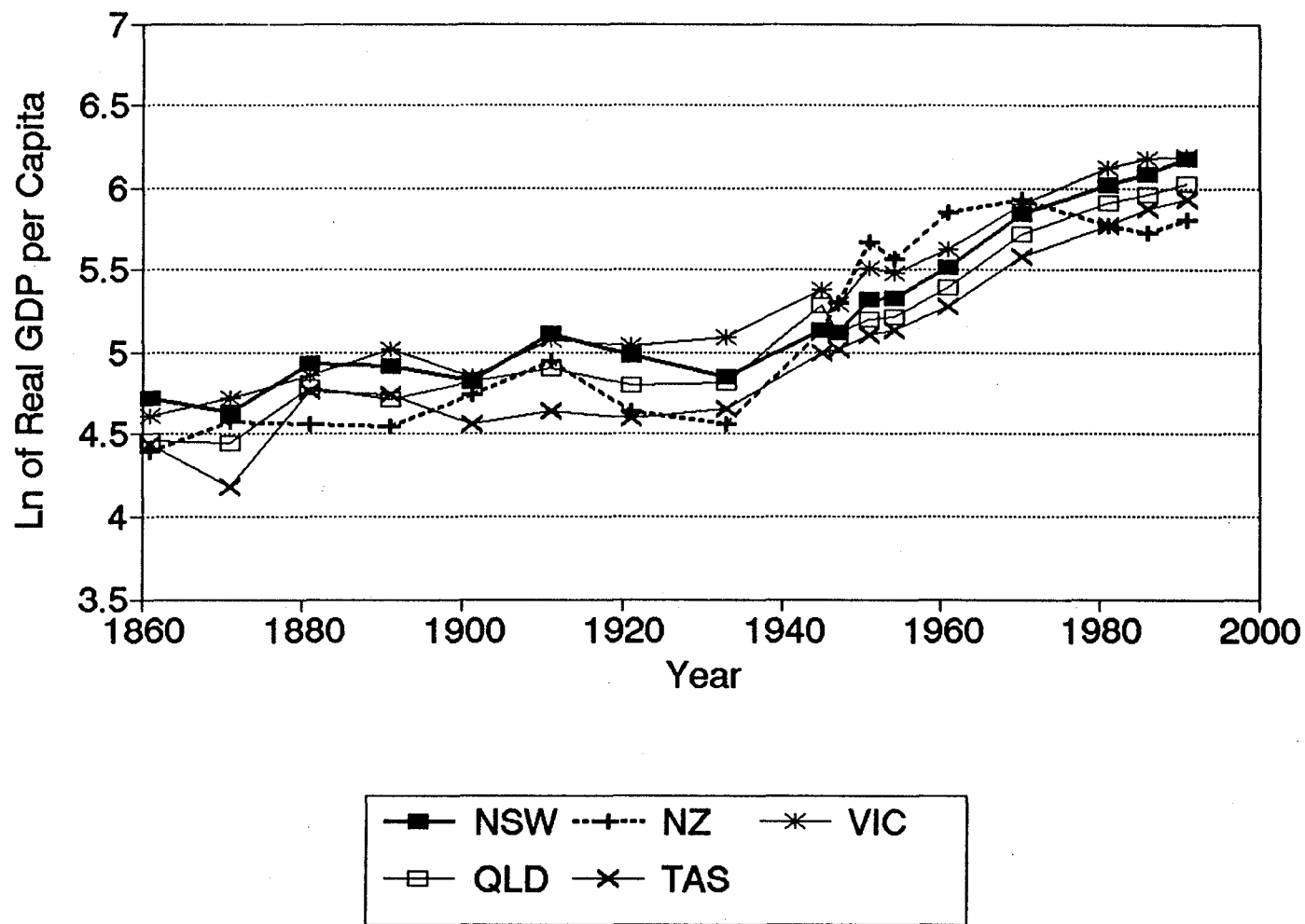


Fig 9 Convergence of Real Per-Capita
GDP: 1901 GDP and GDP Growth 1901-1921

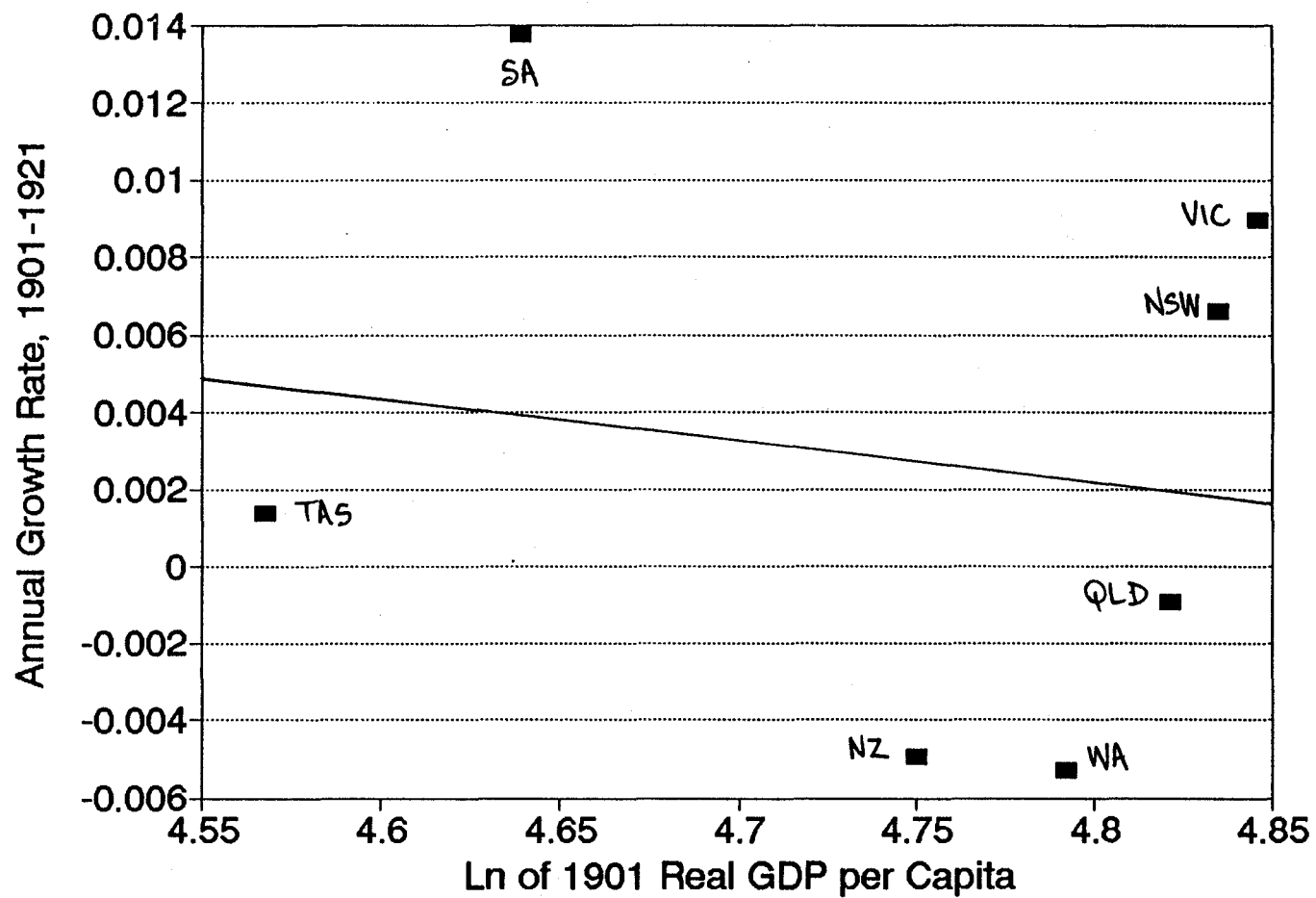


Fig 10 Convergence of Real Per-Capita
GDP: 1861 GDP and GDP Growth 1861-1871

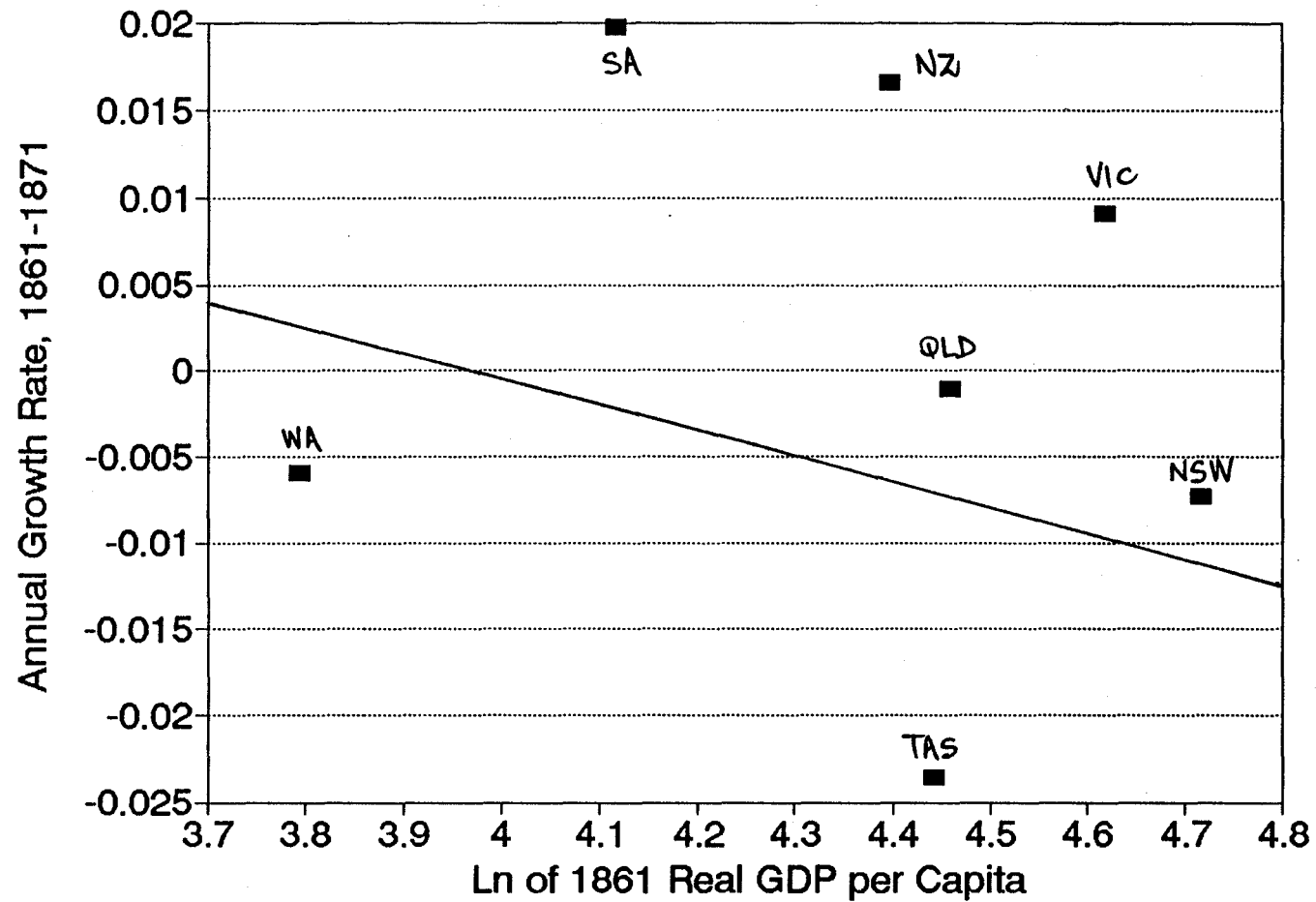
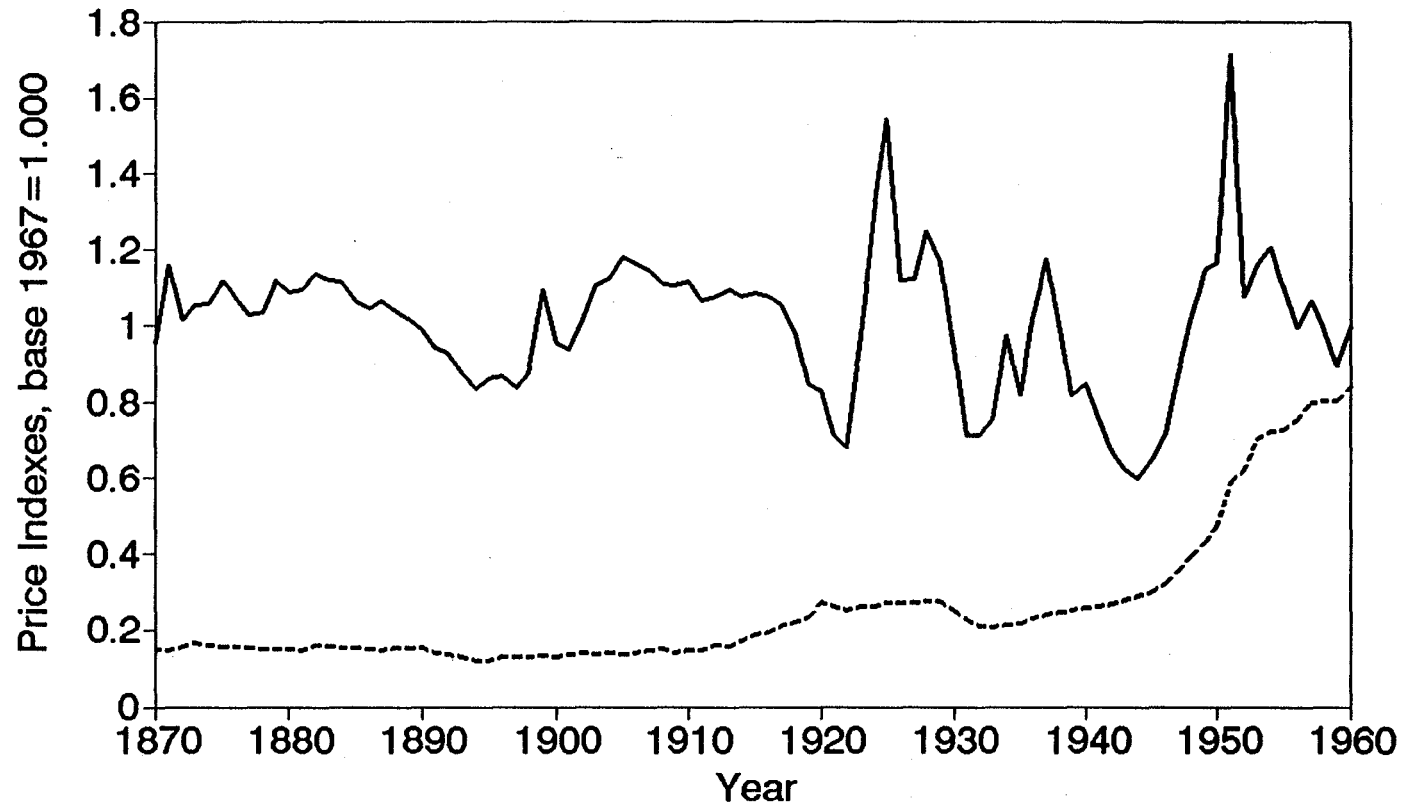


Fig 11 Price Indexes for Terms of Trade
and GDP Deflator, Australia, 1870-1960



— Terms of Trade GDP Deflator

Fig 12 Convergence of Real Per-Capita
GDP: 1901 GDP and GDP Growth 1901-1911

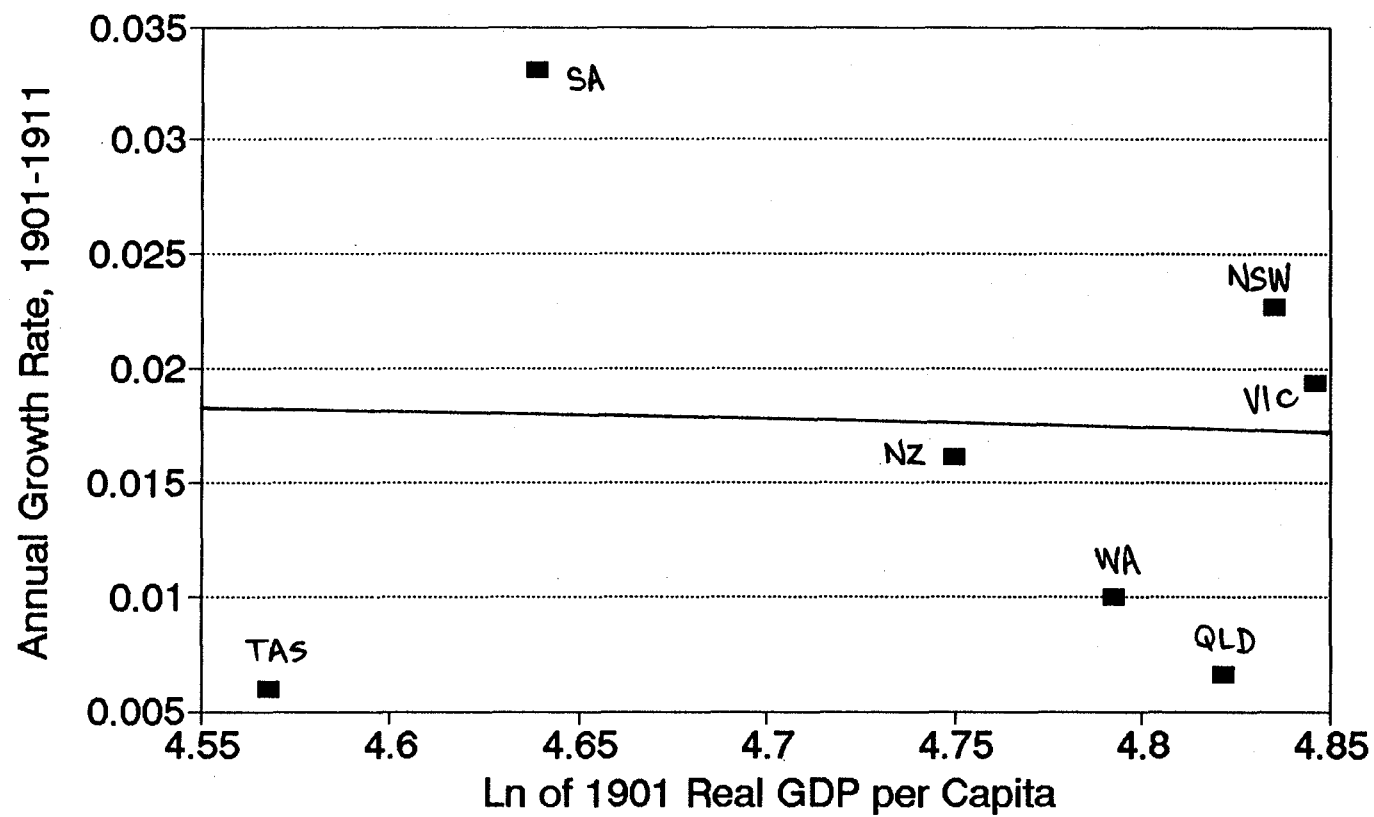


Fig 13 Colony Share of Australian Total
Manufacturing Value Added, 1891-1925

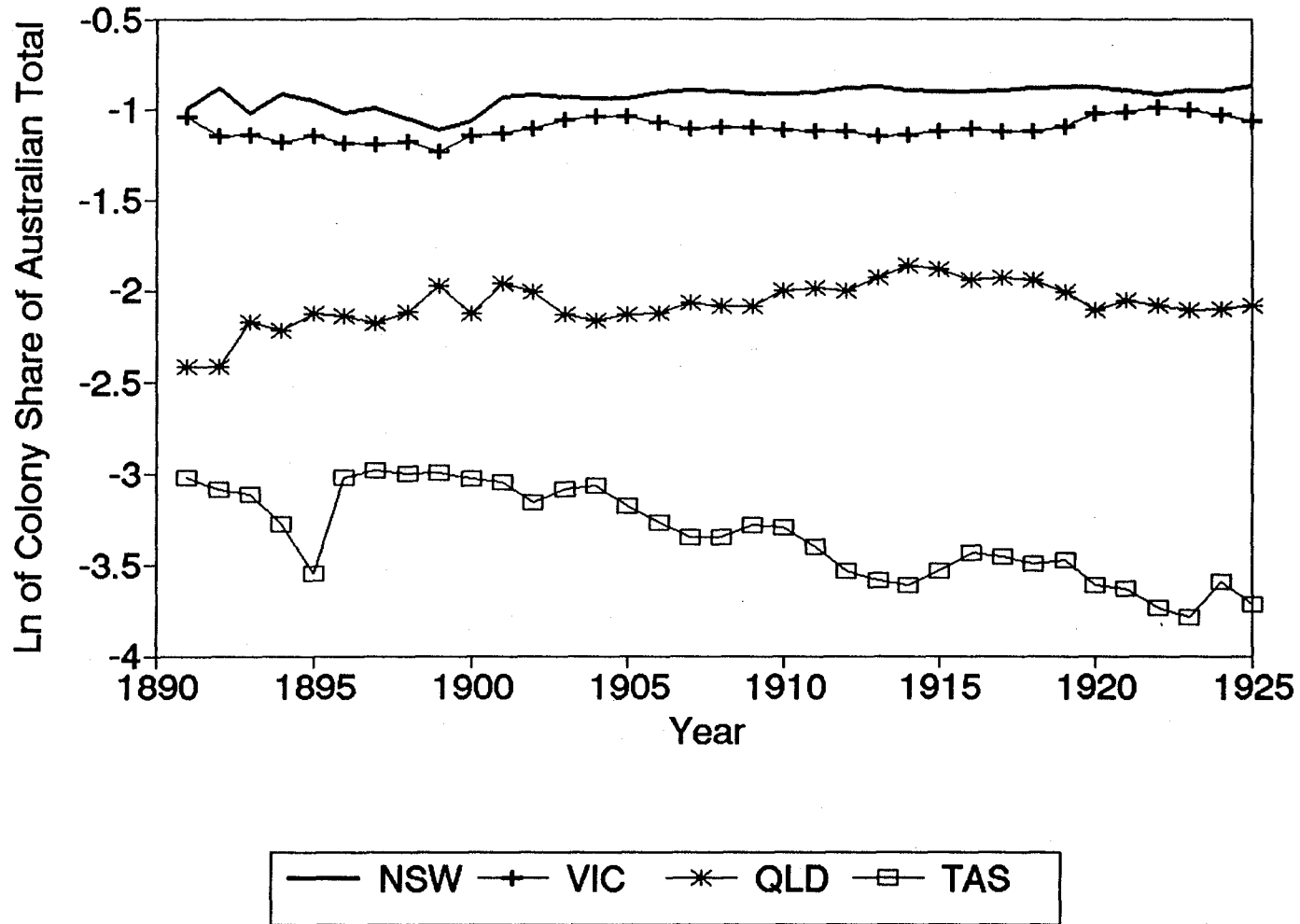


Fig 14 Share of Colony in Total Manufacturing Employment, 1871-1981

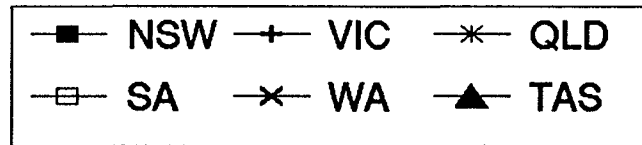
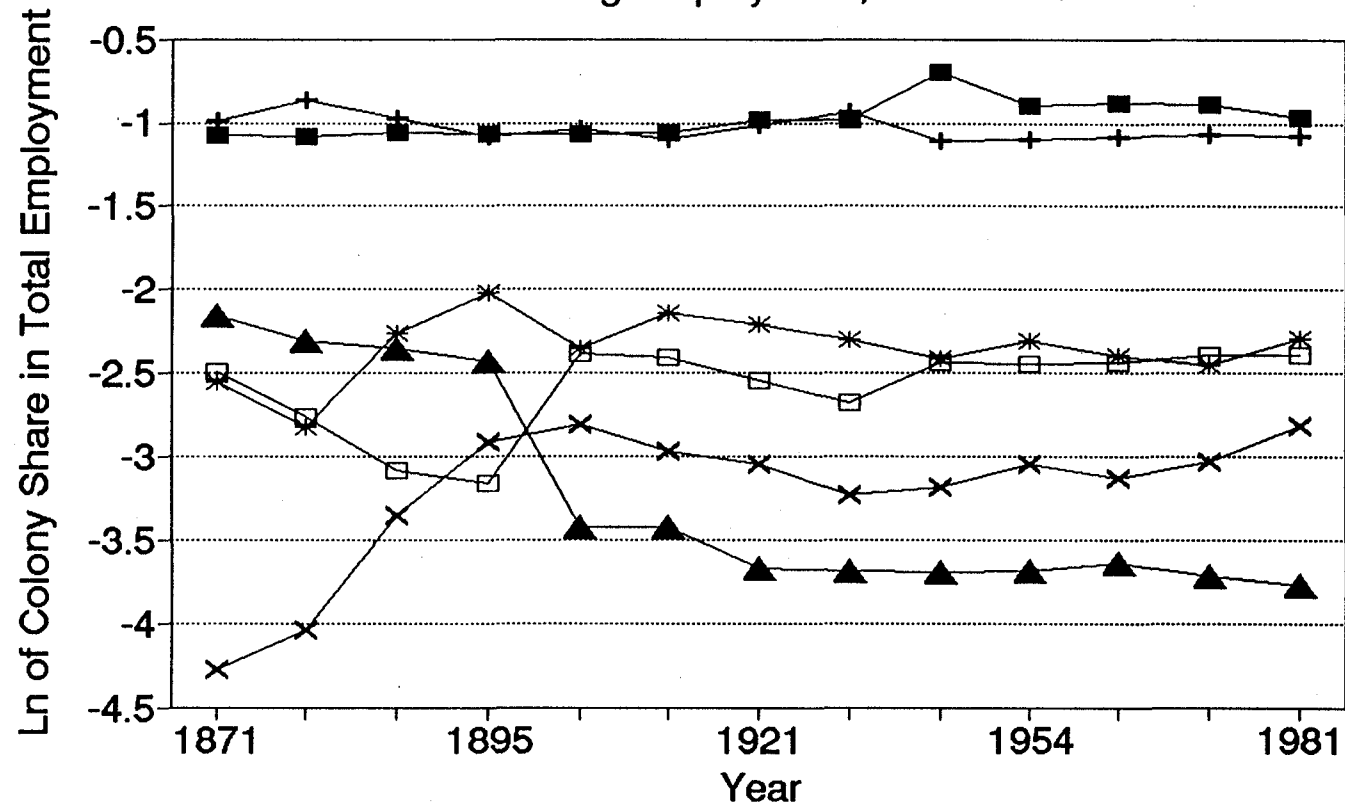


Fig 15 Convergence of Real Per-Capita
GDP: 1911 GDP and GDP Growth 1911-1921

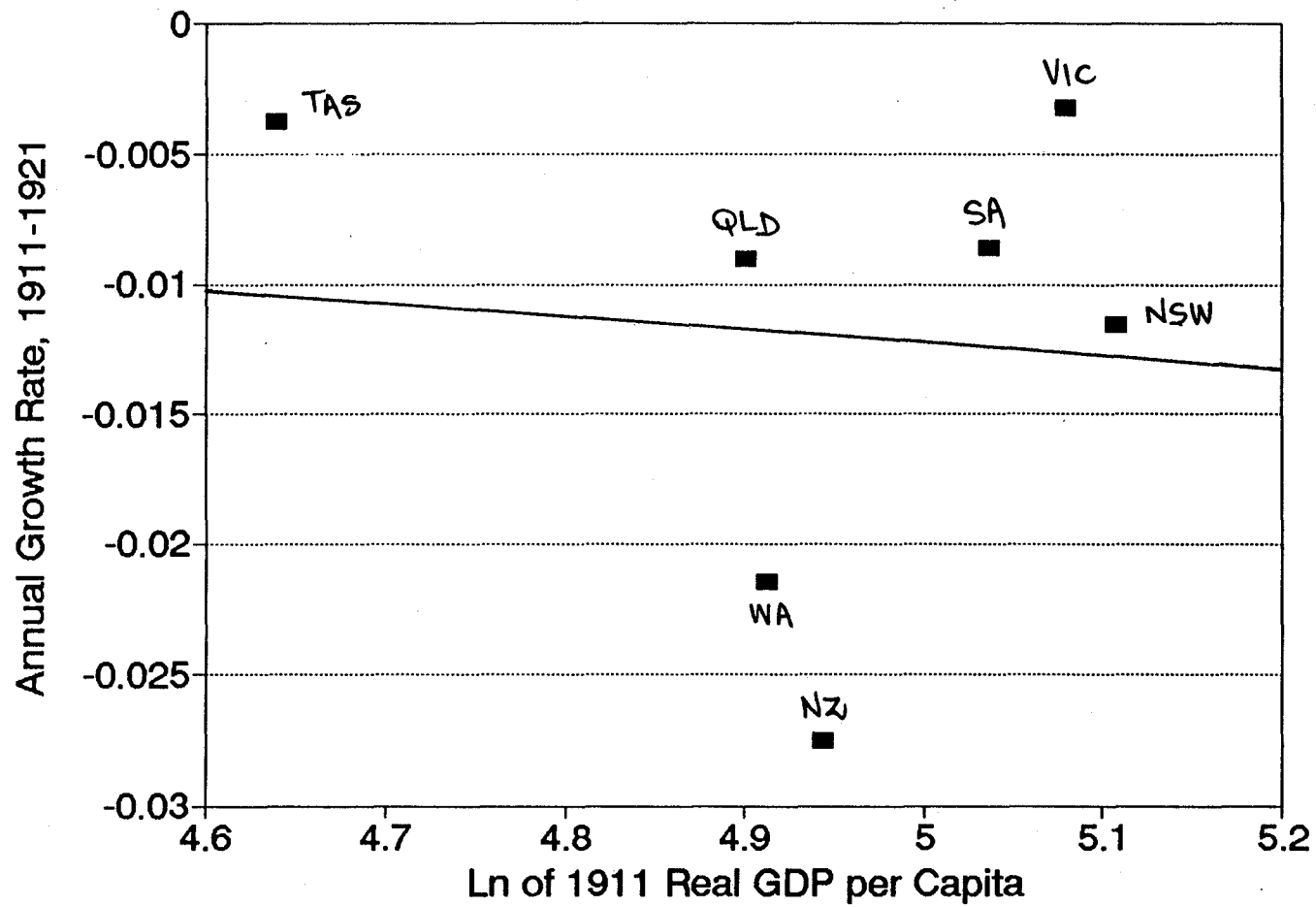


Fig 16 Convergence of Real Per-Capita
GDP: 1947 GDP and GDP Growth 1947-1951

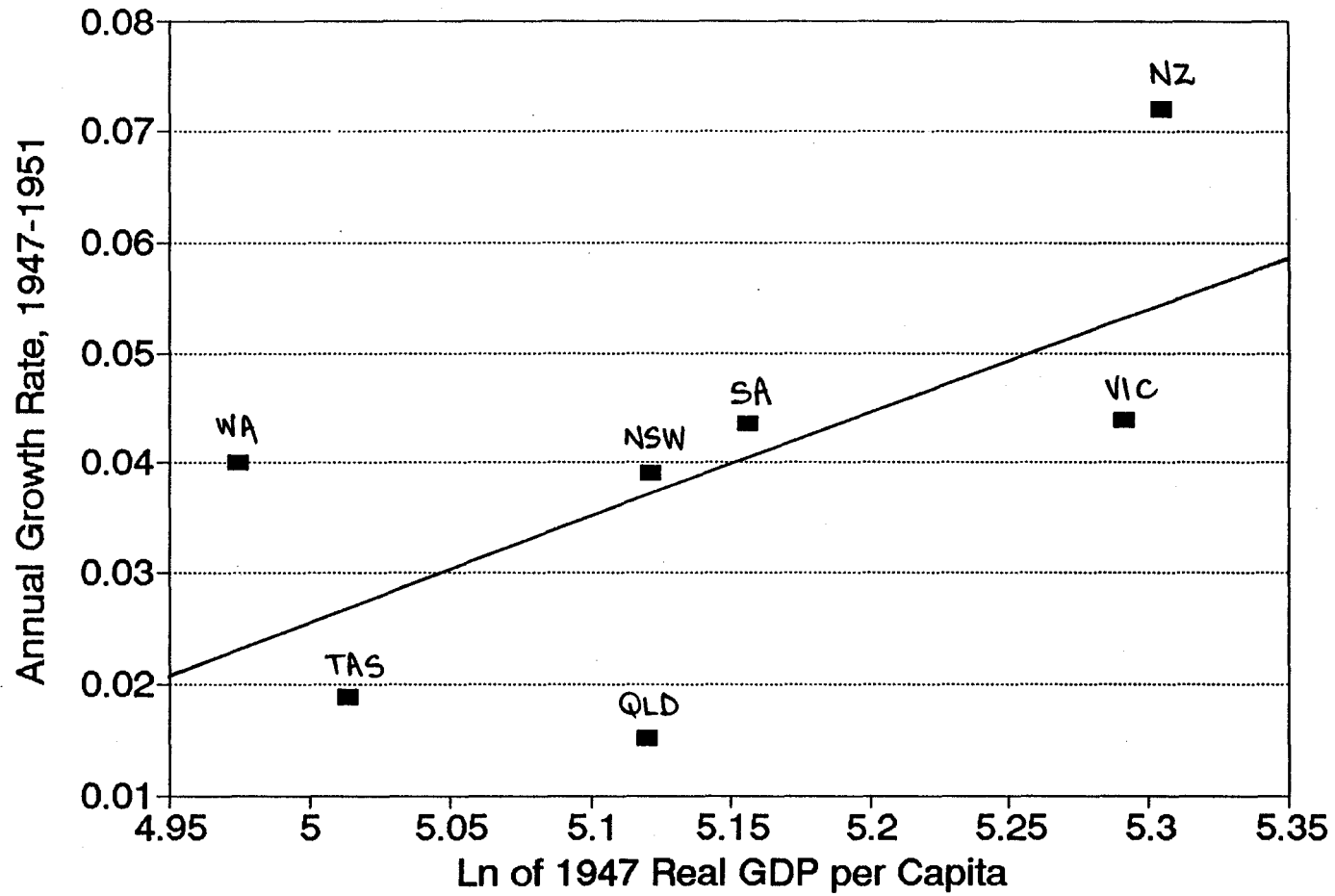


Table 1

**Growth Rates of GDP, GDP Per Capita and Population:
UK, Australia, Canada and the USA, 1860-1979**

	Australia	USA	UK	Canada
1860-1890:				
GDP	4.784 ^a	3.813	1.984	3.080 ^b
GDPCAP	1.049 ^a	1.518	1.064	1.744 ^b
POP	3.338	2.264	0.859	1.325
1860-1913:				
GDP	4.480 ^a	4.745	2.325	4.832 ^b
GDPCAP	1.396 ^a	2.099	1.218	2.569 ^b
POP	2.736	2.109	0.859	1.635
1890-1913:				
GDP	2.030	3.734	1.690	4.113
GDPCAP	0.602	1.880	0.858	0.870
POP	1.849	1.820	0.823	1.969
1913-1950:				
GDP	2.093	2.712	1.258	2.845
GDPCAP	0.520	1.522	0.896	1.268
POP	1.399	1.189	0.258	1.551
1950-1979:				
GDP	4.087	3.410	2.524	4.596
GDPCAP	2.143	2.124	2.219	2.712
POP	1.908	1.243	0.351	1.833
1860-1979:				
GDP	3.308 ^a	3.444	1.878	3.720 ^b
GDPCAP	1.090 ^a	1.782	1.267	1.982 ^b
POP	2.150	1.635	0.556	1.686

Sources and Definitions:

GDP: Annual average compound growth rate of real Gross Domestic Product, at US\$ 1970 prices, taken from Maddison (1982, p.161 and 169-177) and Maddison (1977, Table A-5); **GDPCAP:** Annual average compound growth rate of real GDP per Capita, at US\$ 1970 Prices, taken from Maddison (1982, p.8) and Maddison (1979, p.425-429); **POP:** Annual average compound growth rate of mid-year population, taken from Maddison (1982, p.180-187). Annual average compound growth rates derived from $T \cdot \ln(1+r) = \ln X - \ln A$, where: T is the length of the period of interest in years, X is the value of the series of interest in the final year of the period, A is the value of the series of interest in the initial year of the period, and r is the compound growth rate.

a The period begins in 1861.

b The period begins in 1870.

Table 2
Regressions for GDP Across the Colonies of Australasia

Period	(1)		(2)	
	$\hat{\beta}$ (se)	\bar{R}^2 [$\hat{\sigma}$]	$\hat{\beta}$ (se)	\bar{R}^2 [$\hat{\sigma}$]
1861 1991	0.0077 (0.0016)	0.789 [0.0012]		
1861 1901	0.0223 (0.0036)	0.864 [0.0028]	0.0241 (0.0043)	0.851 [0.0029]
1901 1991	0.0023 (0.0055)	0.157 [0.0014]	0.0050 (0.0061)	0.164 [0.0014]
1861 1891				
1891 1947				
1947 1991				
Restricted	0.0196 (0.0024)	0.846 [0.0025]	0.0269 (0.0022)	0.823 [0.0024]
Wald Test p-value	6.031 0.014		2.215 0.137	

Notes: All regressions use ordinary least squares to estimate equations of the form:

$T^{-1} \ln(y_{it}/y_{i,t-T}) = \alpha - \beta \ln(y_{i,t-T}) + \text{other variables}$, where $y_{i,t-T}$ is the per-capita income in

colony i at the beginning of each period (calculated by the author in Cashin (1993a), deflated by the Australian implicit GDP deflator (for the six Australian states) or the CPI (for NZ).

All regressions are for the seven colonies of Australasia: NSW, VIC, QLD, SA, WA, TAS and NZ. T is the length of each period; 'other variables' is the share of rural employment in each colony's total workforce. Underneath the estimates of β I report the standard errors (in

parentheses), \bar{R}^2 is the adjusted R squared; and [$\hat{\sigma}$] is the standard error of the regression. As noted in the text, all regressions are run with a constant term and some with the share of rural employment as a structural variable, neither of which are reported in the Table. Restricted refers to a combined regression which constrains the value of β to be the same across the equations of a given system, and the restricted β are estimated using linear seemingly unrelated regression, which allows for correlation of error terms across sub-periods. The Wald test and

associated p-value (a χ^2 with $n-1$ degrees of freedom in an n -equation system) refers to the test for equality of the coefficient on the logarithm of initial income across sub-periods of a given system of equations.

Table 2 Continued

Regressions for GDP Across the Colonies of Australasia

Period	(3)		(4)	
	$\hat{\beta}$ (se)	\bar{R}^2 [$\hat{\sigma}$]	$\hat{\beta}$ (se)	\bar{R}^2 [$\hat{\sigma}$]
1861 1991				
1861 1901				
1901 1991				
1861 1891	0.0251 (0.0063)	0.714 [0.0048]	0.0229 (0.008)	0.670 [0.0052]
1891 1947	0.0161 (0.0064)	0.470 [0.0024]	0.0286 (0.004)	0.897 [0.0011]
1947 1991	0.0287 (0.0112)	0.479 [0.0035]	0.0312 (0.007)	0.776 [0.0023]
Restricted	0.0194 (0.0019)	0.442 [0.0021]	0.0274 (0.002)	0.634 [0.0041]
Wald Test p-value	16.581 0.0003		3.300 0.192	

Notes: All regressions use ordinary least squares to estimate equations of the form:

$T^{-1} \ln(y_{it}/y_{i,t-T}) = \alpha - \beta \ln(y_{i,t-T}) + \text{other variables}$, where $y_{i,t-T}$ is the per-capita income in colony i at the beginning of each period (calculated by the author in Cashin (1993a), deflated by the Australian implicit GDP deflator (for the six Australian states) or the CPI (for NZ).

All regressions are for the seven colonies of Australasia: NSW, VIC, QLD, SA, WA, TAS and NZ. T is the length of each period; 'other variables' is the share of rural employment in each colony's total workforce. Underneath the estimates of β I report the standard errors (in

parentheses), \bar{R}^2 is the adjusted R squared; and [$\hat{\sigma}$] is the standard error of the regression. As noted in the text, all regressions are run with a constant term and some with the share of rural employment as a structural variable, neither of which are reported in the Table. Restricted refers to a combined regression which constrains the value of β to be the same across the equations of a given system, and the restricted β are estimated using linear seemingly unrelated regression, which allows for correlation of error terms across sub-periods. The Wald test and associated p-value (a χ^2 with $n-1$ degrees of freedom in an n -equation system) refers to the test for equality of the coefficient on the logarithm of initial income across sub-periods of a given system of equations.

Table 3

**Customs and Excise Tax Revenue as a Percentage of Total Revenue,
Colonial/State Governments, 1881-1902**

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1881	21.87	31.03	32.35	26.06	42.13	52.96	37.72
1885	24.83	32.26	35.65	23.95	41.18	49.40	36.84
1891	24.75	32.27	38.87	23.12	47.19	44.51	37.45
1895	23.71	31.15	35.22	21.52	45.20	42.38	37.58
1901	8.85	15.59	19.21	11.61	16.69	26.76	38.36
1902	0	0	0	0	0	0	37.24

Source: Barnard (1985,1985a-c,1986,1986a-c); Coghlan (1904); Registrar General's Office (1892, 1910, 1915).

Table 4

**Federal Transfer Payments as a Percentage of
State Government Total Revenue, 1901-1921**

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1901	8.32	15.27	14.23	11.26	14.89	45.76	0
1905	22.31	26.83	20.95	19.75	28.43	30.36	0
1911	14.03	17.58	12.93	12.17	14.81	23.51	0
1915	12.08	16.70	11.49	13.67	11.81	27.09	0
1921	7.44	9.85	7.23	8.24	8.32	17.24	0

Source: Barnard (1985,1986).

Table 5
Taxation Revenue as a Percentage of
Total Revenue, Colonial/State Governments, 1891-1921

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1891	29.44	38.21	45.64	30.73	51.20	56.85	48.35
1895	28.77	39.75	41.54	32.20	48.40	60.89	51.72
1901	18.67	24.59	27.27	21.58	21.42	13.56	51.51
1905	9.83	11.95	12.66	15.87	6.14	25.44	51.10
1911	7.43	14.61	12.53	13.06	8.44	29.38	46.98
1915	15.61	16.73	13.24	14.83	7.24	29.58	47.23
1921	21.71	20.18	29.23	22.68	14.06	33.63	64.75

Sources: Barnard (1985,1986); Census and Statistics Office (1926, p.881).

Table 6
Income Tax Revenue as a Percentage of
Total Revenue, Colonial/State Governments, 1891-1921

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1891	0	0	0.98	1.67	0	1.24	0
1895	0	2.09	1.67	2.33	0	6.43	0
1901	1.93	2.85	1.68	3.07	2.29	2.54	2.94
1905	1.72	4.21	7.06	4.91	3.43	9.73	3.46
1911	1.94	4.30	6.56	4.04	3.48	11.96	3.95
1915	8.73	4.81	7.17	5.94	3.40	12.70	4.33
1921	12.93	8.34	19.05	11.91	8.52	16.53	24.08

Sources: Barnard (1985,1986); Registrar General's Office (1892, 1910, 1915, 1921); Census and Statistics Office (1926).

Table 7

**Income Tax Revenue as a Percentage of
GDP, Colonial/State Governments, 1891-1921**

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1891	0	0	0.16	0.26	0	0.14	0
1901	0.006	0.32	0.24	0.52	0.67	0.28	0.21
1911	0.19	0.37	0.86	0.53	0.69	1.17	0.27
1921	1.59	0.74	2.89	1.36	1.80	1.82	3.14

Sources: Barnard (1985,1986); Author's calculations, see Appendix A;
Registrar General's Office (1892, 1910, 1915); Census and Statistics Office (1926).

Table 8

**Public Debt of Colonial/State Governments as a
Percentage of Colony/State GDP, 1881-1921**

Year	NSW	VIC	QLD	SA	WA	TAS	NZ
1881	32.62	40.32	103.42	77.41	49.25	29.47	49.35
1891	72.59	53.42	141.36	120.61	61.52	88.67	64.09
1901	90.47	98.25	137.47	157.09	125.67	119.79	60.11
1911	73.65	71.77	116.81	90.73	127.69	117.89	54.62
1921	67.13	54.32	97.50	82.15	158.22	106.74	78.44

Sources: Barnard (1985,1986); Author's calculations, see Appendix A; Census and Statistics Office (1926, p.880).

Table 9
Intercolonial^a Exports as a Share of Each Colony's Total Exports, 1883-1909

Year	NSW	VIC	SA	QLD	WA	TAS	NZ ^b
1883	46.3	35.0	37.5	61.9	19.2	75.6	15.6
1884	47.7	44.3	35.3	62.5	16.2	76.8	22.9
1885	41.9	36.2	na	54.0	14.6	85.4	19.8
1886	49.6	34.9	na	57.4	12.0	81.4	25.5
1887	48.6	39.5	na	67.3	15.3	75.8	21.2
1888	47.8	36.3	37.1	66.9	18.0	86.5	20.1
1889	48.2	35.9	45.5	67.0	27.0	85.6	23.0
1890	52.8	35.1	40.2	71.7	28.4	82.5	16.7
1891	46.5	33.8	47.0	59.8	30.8	75.9	17.8
1892	41.0	27.9	46.1	54.3	35.7	76.5	14.3
1893	43.1	27.1	42.1	60.5	52.2	78.7	14.2
1894	40.0	24.7	44.6	64.0	66.3	85.0	9.4
1895	34.5	30.7	43.5	60.9	70.0	85.0	12.1
1896	36.4	37.8	47.0	59.9	58.3	88.0	13.8
1897	34.4	29.7	42.7	62.3	50.3	83.5	13.2
1898	31.3	41.8	49.8	57.6	49.6	74.9	14.0
1899	33.4	28.1	44.0	59.1	42.0	46.5	14.3
1900	38.6	32.8	49.3	57.3	16.4	42.0	14.0
1901	36.7	32.4	46.1	53.5	6.9	44.4	15.5
1902c							19.7
1903c							14.9
1904c							12.3
1905	39.4	42.8	32.6	58.2	8.3	49.9	14.7
1906	38.1	43.0	32.9	54.9	8.1	36.3	15.9
1907	38.9	46.1	33.5	51.5	13.7	39.2	11.0
1908	41.6	49.1	36.1	50.9	11.3	49.8	16.3
1909d	43.3	45.7	28.9	51.3	24.6	51.1	17.6

Notes:

- a Defined as exports to the other six Australasian colonies.
- b Note NZ is included in intercolonial trade during 1901-1909, rather than international trade.
- c 1902-1904 unavailable for the Australian states.
- d Recording of interstate trade was abolished in 1910.
- na Not available.

Sources: Fairburn (1970, p.219); Registrar-General's Office (1921); CBCS (1911, p.667).

Appendix A

Data on the Seven Colonial Economies, 1861–1991

The following Table presents descriptive statistics for the data used in this paper.

Table A1

Data for the Seven Colonial Economies, 1861–1991

Variable	Year(s)	Mean	Standard Deviation
Logarithm of Per-Capita GDP ^a	1861	4.363	0.291
	1871	4.375	0.314
	1881	4.686	0.213
	1891	4.775	0.142
	1901	4.750	0.099
	1911	4.945	0.146
	1921	4.812	0.166
	1933	4.785	0.164
	1947	5.140	0.116
	1954	5.335	0.156
	1961	5.488	0.188
	1970	5.769	0.117
	1981	5.903	0.117
	1991	6.046	0.136
Growth of Per-Capita GDP ^b	1861–1871	0.001	0.014
	1871–1881	0.028	0.017
	1881–1891	0.008	0.016
	1891–1901	-0.002	0.013
	1901–1911	0.018	0.010
	1911–1921	-0.012	0.008
	1921–1933	-0.002	0.005
	1933–1947	0.024	0.011
	1947–1954	0.024	0.008
	1954–1961	0.019	0.009
	1961–1970	0.028	0.010
	1970–1981	0.011	0.010
1981–1991	0.013	0.007	

Table A1 Continued

Share of Agricultural Employment ^c			
	1861	0.315	0.093
	1871	0.337	0.073
	1881	0.323	0.033
	1891	0.274	0.034
	1901	0.243	0.058
	1911	0.244	0.038
	1921	0.239	0.037
	1933	0.228	0.040
	1947	0.157	0.031
	1954	0.144	0.028
	1961	0.120	0.026
	1970	0.084	0.017
	1981	0.070	0.017

Sources: Author's calculations, see Cashin (1993a); Vamplew (1987); Bloomfield (1984).

a The logarithm of per-capita income is the natural logarithm of real per-capita GDP in colony i at time t , $\ln(y_{it})$, where y_{it} is calculated as real per-capita GDP in 1911 Australian dollars (A\$).

b The growth of per-capita GDP is the annual average growth rate of real per-capita GDP in colony i between the period $t-T$ and t : $(1/T)\ln(y_{it}/y_{i,t-T})$, where T is the length of the period.

c For the six Australian colonies the employment share variable is the share of employment in the rural industries of each colony as a share of the total workforce in each colony, as measured at census dates. For NZ the employment share variable has the economically active population as the denominator, and the numerator is agricultural and pastoral employees (for 1861-1921), and agricultural employees (for 1933-1981). NZ uses 1945 census data for its 1947 estimate, and 1956 census data for its 1954 estimate. All other years coincide with Australian census years.

Appendix B

Bias from Using the Monetary-Based Technique for Correctly-Estimated Initial Incomes and Incorrectly-Estimated Subsequent Incomes

Estimated $\hat{\beta}$ -Convergence

Here it is assumed that initial income, $\ln(\hat{y}_{i,t-T})$, is measured correctly [$\ln(\hat{y}_{i,t-T}) = \ln(y_{i,t-T})$] and all incomes in subsequent periods, $\ln(\hat{y}_{it})$, are measured with error [$\ln(\hat{y}_{it}) \neq \ln(y_{it})$]. Accordingly, the estimated speed of convergence ($\hat{\beta}$) in (8) is:

$$(B1) \quad -\hat{\beta} \equiv \text{cov}[\ln(\hat{y}_{i,t-T}), T^{-1}(\ln(\hat{y}_{it}) - \ln(\hat{y}_{i,t-T}))] / \text{var}[\ln(\hat{y}_{i,t-T})].$$

Given the above assumptions, (B1) can be rewritten as:

$$(B2) \quad -\hat{\beta} \equiv \text{cov}[\ln(y_{i,t-T}), T^{-1}((1+\varphi)\ln(y_{it}) - \ln(y_{i,t-T}))] / \text{var}[\ln(y_{i,t-T})]$$

where $\ln(\hat{y}_{it}) = (1+\varphi)\ln(y_{it}) + \text{constant}$, as in footnote 6, and so (B2) can be rewritten as:

$$(B3) \quad -T\hat{\beta} \equiv \{\text{cov}[\ln(y_{i,t-T}), (1+\varphi)\ln(y_{it})] - \text{var}[\ln(y_{i,t-T})]\} / \text{var}[\ln(y_{i,t-T})]$$

and so for $(1+\varphi)$ constant:

$$(B4) \quad -T\hat{\beta} \equiv (1+\varphi)\text{cov}[\ln(y_{i,t-T}), \ln(y_{it})] / \text{var}[\ln(y_{i,t-T})] - 1.$$

When $\varphi=0$ in (B4) then the true β -coefficient is:

$$(B5) \quad -T\beta \equiv \text{cov}[\ln(y_{i,t-T}), \ln(y_{it})] / \text{var}[\ln(y_{i,t-T})] - 1.$$

Accordingly, the bias from using the monetary-based technique is:

$$(B6) \quad (-\hat{\beta}) - (-\beta) = T^{-1}\varphi\text{cov}[\ln(y_{i,t-T}), \ln(y_{it})] / \text{var}[\ln(y_{i,t-T})],$$

which using (B5) can be rewritten as:

$$(B7) \quad (-\hat{\beta}) - (-\beta) = \varphi(T^{-1}\beta).$$

Estimated $\hat{\sigma}$ -convergence

For $\ln(\hat{y}_{i,t-T}) = \ln(y_{i,t-T})$, that is the initial income measured without error, yet all subsequent income estimates measured with error, then the following section sets out the effects on estimated σ -convergence. In examining the implications of measurement error for the calculation of σ -convergence, let us again denote $Y_i = M_i V_i$ as the true nominal income of colony i , and $\hat{Y}_i = M_i V_a$ its monetary-based estimate, with the lower case terms (y_i and \hat{y}_i) their per-capita equivalents and L_i the population of colony i . As noted above, let us also denote V_a as the Australian income velocity of money, and y_a the Australian (weighted average) per-capita income.

Suppose for simplification that we assume there are just two regional economies in Australasia (one rich and one poor), and that the difference in $\ln(y)$ for these two growing economies i (rich) and j (poor) is the same at time $t-T$ and at time t . Then in reality there is neither β -convergence (the speed of convergence of the initially-poor economy to the initially-rich economy is zero) nor σ -convergence (the dispersion of the $\ln(y)$ is constant) over this period.

What will be the bias in the estimation of σ -convergence induced by the monetary-based estimates of nominal colonial GDPs? If, as argued in Section 4, money is regarded as a luxury good ($\eta > 1$), then the income velocity of money will fall over time as income rises. Accordingly, the rich economy will have a relatively low income velocity of money (that is, $y_i > y_a$ induces $V_i < V_a$), which results in the estimated colonial per-capita income exceeding the true colonial per-capita income $[(M_i V_a)/L_i = \hat{y}_i > y_i = (M_i V_i)/L_i]$. The converse will occur for the poor economy with $y_j < y_a$ (inducing $V_j > V_a$): for it the monetary-based estimates (when again $\eta > 1$) yield an estimated per-capita colonial income which is less than the true colonial per-capita income $[(M_j V_a)/L_j = \hat{y}_j < y_j = (M_j V_j)/L_j]$.

The result will be the erroneous appearance of both β -divergence (the initially-rich economy appears to be becoming relatively richer, and the initially-poor economy relatively poorer) and σ -divergence (the dispersion of $\ln(\hat{y})$ across the economies appears to be growing) between periods $t-T$ and t , when in actuality there was no divergence at all. The opposite result (erroneous β - and σ -convergence) will occur for money as an inferior good ($\eta < 1$).

In the case where there is indeed actual β - and σ -convergence across economies between periods $t-T$ and t , then for $\eta > 1$, $\ln(\hat{y}_{i,t-T}) = \ln(y_{i,t-T})$ and $\ln(\hat{y}_{it})$ $\forall t$ estimated with error using the monetary-based technique, both the speed of estimated β -convergence will be slower ($\hat{\beta}$ will be biased toward zero, as set out above) and the estimated σ -convergence will appear slower than it truly is.

Appendix C

Notes on Sources for the Figures

Figure	Sources
1	Maddison (1977, 1979, 1982).
2	Author's calculations, see Appendices A and B of Cashin (1993).
3-10	As for 2.
11	Wilson (1931, p.29); Maddock and McLean (1987, p.356-357); Vamplew (1987); Australian Bureau of Statistics (1992).
12	As for 2.
13	Butlin (1962).
14	Vamplew (1987).
15-16	As for 2.

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