

Theories of local economic growth (part 2): model specification and empirical validation

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Abstract. This study is an attempt to produce a theoretically informed econometric analysis of dynamic regional economic performance. The first paper in this two-part study highlighted the problems and possibilities of translating the propositions contained in six ‘soft’ theories of local economic growth into measurable dimensions and sets of proxy variables that are hypothesized to determine local economic growth. This second paper focuses on issues of econometric-model design and empirical validation. Given the practical limitations imposed by data availability, the ‘soft’ theories of local economic growth are modeled by a simple conditional ‘gap’ convergence model in which prevailing regional unemployment relativities are determined by a common trend in unemployment and a set of regionally specific variables. The empirical validity of the competing ‘soft’ theories of local economic growth is evaluated by applying test restrictions imposed by the ‘soft’ theories to a general model specification containing eight regionally specific variables that have been identified as potential drivers of local economic growth. The econometric modeling of Australian data suggests that the processes of regional economic performance might be somewhat different from those specified in individual theoretical models. Significantly, the role of local ‘enterprise culture’ is revealed—built on specialization, technological leadership, human resources, and the local integration of firms—though significant caveats are attached to the roles of access to information, institutional support, and interregional trade as promoters of local economic growth.

1 Introduction

This study is intended to contribute to a ‘third way’ of knowing in economic geography that transcends the ‘hard’ models derived from conventional economics and the ‘soft’ models that are characteristic of much that passes for explanation in contemporary economic geography. In the first paper in this study (Plummer and Taylor, 2001) we focused on questions of methodology and measurement. A set of six competing theories of local economic growth were reviewed: the growth-pole, growth-centers model, the product-cycle model, the flexible-production model, the learning-regions model, the competitive-advantage model, and the enterprise-segmentation model. This set of competing theoretical propositions was characterized in terms of eight measurable dimensions which have been calibrated using regional economic data for Australia from the period 1984–92 (see table 1, over, for a summary of these variables). In this paper, we attempt to evaluate empirically the set of six competing theories of local economic growth using the eight measurable dimensions.

In general terms, model validation entails employing a suitably formulated modeling methodology in such a way as to bring empirical evidence to bear on the claims formulated in our theoretical propositions (Dhammika and McAleer, 1996). That is, we need to formulate an empirically estimable model that is derived from our ‘soft’

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Table 1. Summary of surrogate variables for the theoretical dimensions.

Variable	Theoretical dimension	Description of surrogate
<i>T</i>	Technological leadership at the enterprise level	Index of high-technology industries (data from the late 1980s)
<i>I</i>	Knowledge creation and access to information	Index of access to information (data from the late 1980s)
<i>M</i>	Local integration of small firms	Percentage of establishments in multilocal enterprises (from 1992)
<i>P</i>	Infrastructure support and institutional thickness	Effective protection rate (in 1990)
<i>D</i>	Local human resource base	Percentage of working population without a degree (in 1991)
<i>C</i>	Power of large corporations affecting structure and strategy	Index of corporate control (from 1992)
<i>A</i>	Interregional trade and the extent and nature of local demand	Index of intermediate market accessibility (data from the late 1980s)
<i>S</i>	Local sectoral specialization	Index of specialization (from 1990)

theories and that can be evaluated in light of the empirical evidence that is available. In practice, evaluating competing 'soft' theories of local economic growth using regional economic information derived from the Australian economy is a challenging task which entails confronting vaguely formulated sets of theoretical propositions with empirical evidence that is limited in terms of both quantity and quality (Plummer and Taylor, 2001).

The set of 'soft' theories is vague in the sense that, typically, the theoretical propositions contained in the individual theoretical models are either ambiguous or lack clarity of expression. Although it is possible to identify the measurable dimensions that cover the propositions contained in these 'soft' theories, assessing their hypothesized impact on regional economic performance is more ambiguous. The 'soft' theories offer little by way of guidance as to the possible form of the functional relationship between the set of measurable dimensions and local economic performance. In addition, in the Australian context, empirical evidence consists of a relatively short spatial time-series of unemployment rates and a set of aggregated cross-sectional measurable dimensions that are intended to capture the processes driving regional economic growth. As with most studies of regional economies, the limited quantity and quality of the empirical information that is available mean that it may not be possible to implement available empirical tests about the dynamics of regional economic growth (Plummer, 2000).

One response to the practical limitations of model validation in a regional economic context is to do nothing and forego any attempt at econometric modeling: we cannot test 'soft' theories and we should not try. Such an approach places too high a degree of belief in our set of theoretical presuppositions. Given the complexity of geographical reality and the practical limitations of empirical evaluation, we agree that it is not plausible to aim for an econometric model that completely captures the subtleties of the 'soft' theories of local economic growth. The reduction of a complex geographical world to an estimable econometric model inevitably entails a discrepancy between the theoretical information provided by our set of 'soft' theories and the available empirical information. This discrepancy is the result of the set of nonsystematic measurement errors, omitted variables, and approximations that are made when formulating the estimable econometric model (Darnell and Evans, 1990; Morgan, 1988). As in any

modeling situation, we cannot know for certain whether a lack of correspondence between our theoretical presuppositions and the available empirical evidence is the result of the falsity of our target theory or the approximations and omissions that we employed in specifying the empirical model (Chalmers, 1987; Laudan, 1990). However, even in the absence of an adequate empirical basis for our explanatory claims, it is possible to aim for conjectural knowledge of the processes driving local economic growth. It is always possible that our findings can be overturned in the light of new empirical evidence, more accurate measurement systems, better estimation methods, or more sophisticated theoretical models.

In practice, empirical modeling is not a simple process of confronting theory with empirical evidence. Rather, empirical model design entails a complex and iterative process involving the confrontation, and subsequent revision, of an empirical model specification to meet a set of predetermined model design criteria. Given the vagueness of the 'soft' models of local economic growth, in this paper we initially formulate an estimable econometric model of local unemployment relativities that is based upon a simple conditional 'gap' convergence model. In this type of empirical model, prevailing regional unemployment relativities are hypothesized to depend upon a common trend in regional unemployment between regions, a set of regionally specific variables, and a set of 'random' shocks. Even based upon a relatively small set of eight measurable dimensions of the processes driving local economic growth, a large number of combinations of regionally specific variables are possible. Rather than pursuing a data-driven variable-selection strategy, in this paper we employ a more theory-driven approach in which the information from our 'soft' theories is used as a guide to simplifying a general model specification that contains all eight of our measurable dimensions.

2 Empirical model design

Other than identifying the set of potential explanatory variables that should enter an econometric model, the 'soft' theories of local economic growth provide little guidance as to the form of an estimable empirical model. In contrast, recent advances in econometrics have established a suite of econometric techniques that permit researchers to evaluate competing hypotheses about the types of dynamic processes that underpin observed economic time-series (Hendry, 1995). Unfortunately, with a few notable exceptions, it has not been possible to extend these techniques to modeling the dynamics of regional economic systems (Blanchard and Katz, 1992; Martin, 2000). We simply do not possess adequate regional economic (panel) data to conduct this type of sophisticated hypothesis testing in the regional context. Rather, faced with limited cross-sectional empirical information collected at multiple time periods, it is conventional to design models based on growth regressions (Armstrong and Vickerman, 1995). These simple mean-reversion techniques relate the economic growth rate in a region to a common trend, a set of observation-specific structural variables, and a series of random 'shocks' (Martin and Sunley, 1998). Growth-regression models have been widely criticized for prioritizing changes in the moments of a distribution of regional growth rates (level, spread, shape) over the movement of individual regions within that distribution (Fingleton, 1999; Quah, 1993). However, they do permit us to make economically meaningful statements about the determinants of local economic growth using limited amounts of regional economic data.

We postulate a simple 'gap convergence' model relating regional unemployment relativities at the end of a given period (R_{it}), to regional unemployment relativities at the start of that period ($R_{it-\tau}$) (Baddeley et al, 1998). This type of 'gap convergence' model can be estimated using ordinary least squares (OLS) regression. The use of OLS estimation allows us to employ a battery of powerful diagnostic tests to evaluate

the data coherence of our model specification. In addition, the properties of OLS estimation will prove useful when evaluating the relative explanatory significance of our competing models of local economic performance (Amemiya, 1985).

When a 'gap convergence' model is used, the trend in regional unemployment differentials reflects, at least potentially, both a mean reversion towards a common steady-state configuration of relative unemployment levels and differences in the local economic conditions prevailing between regions (Sala-i-Martin, 1996; Valdes, 1999). Formally,

$$\ln(R_{it}) = \beta_0 + \beta_1 \ln(R_{it-\tau}) + \sum_j \beta_j X_{ij,t-\tau} + \varepsilon_{i,t,t-\tau}, \quad (1)$$

where $\beta_j, j = 2, \dots, k$ are unknown parameters, $X_{ij,t-\tau}$ is the j th covariate associated with region i at time $t - \tau$, and $\varepsilon_{i,t,t-\tau}$ defines a set of random and serially uncorrelated shocks to a region's unemployment relativity. In the context of this model, β_1 defines the speed of convergence in regional unemployment relativities. In the absence of regionally specific steady-state disparities between regions (that is, if $\beta_2, \dots, \beta_k = 0$), if $0 < |\beta_1| < 1$ then regional unemployment relativities will converge to a common mean, whereas $|\beta_1| > 1$ implies divergence of regional unemployment rates, and $|\beta_1| = 1$ implies stable unemployment relativities. Accordingly,

$$\sum_j \beta_j X_{ij,t-\tau}$$

represents the set of regionally specific effects, reflecting the set of local capacities in each region.

As with any empirical modeling, evaluating the six competing 'soft' models entails establishing a degree of congruence between our sample information on the Australian economy and the underlying 'gap convergence' regression model, in light of our theories of local economic growth. In this paper, we employ a general-to-specific modeling strategy to evaluate the six competing 'soft' models of local economic growth. A general-to-specific modeling strategy begins with an overparameterized model that is tested down to a more specific model. This model is subjected to a battery of misspecification tests to establish its 'congruence' with the evidence (Charemza and Deadman, 1997; Kennedy, 1992). Within contemporary econometrics, general-to-specific modeling has been widely advocated as an efficient strategy that incorporates both sample and theoretical information in an empirical modeling framework (Spanos, 1990; and compare Hepple, 1996).

On the basis of our theoretical information, the six competing models developed in the previous paper (Plummer and Taylor, 2001, table 2) can be nested within an overparameterized model:

$$\begin{aligned} \ln(R_{it}) = & \beta_0 + \beta_1 \ln(R_{it-\tau}) + \beta_2 T + \beta_3 I + \beta_4 M + \beta_5 P + \beta_6 D + \beta_7 C \\ & + \beta_8 A + \beta_9 S + \varepsilon_{i,t,t-\tau}. \end{aligned} \quad (2)$$

To establish whether this general model captures any specific information that is not embodied in the 'soft' theoretical models, we employ a variance encompassing procedure to test the validity of the restrictions that are imposed on this general model by our 'soft' models. The encompassing model is defined as the model that variance-dominates the set of alternative model specifications in the sense that the other models contain no information capable of improving the model (Hendry and Mizon, 1990; McAleer, 1994). Assuming that the linear restrictions imposed on this general model are correct, the six competing models have the following associated null hypotheses:

Competitive advantage:	$H_0: \beta_7 = 0.$
Learning regions:	$H_0: \beta_7 = \beta_8 = 0.$
Flexible specialization:	$H_0: \beta_3 = \beta_7 = \beta_8 = \beta_9 = 0.$
Product cycle:	$H_0: \beta_4 = \beta_5 = \beta_9 = 0.$
Growth pole:	$H_0: \beta_4 = \beta_5 = \beta_6 = \beta_8 = \beta_9 = 0.$
Segmentation:	$H_0: \beta_3 = \beta_5 = \beta_6 = \beta_8 = \beta_9 = 0.$

Note that, following the same nesting logic, the learning-regions model and the flexible-specialization model can be nested within the competitive-advantage model, and the growth-pole model can be nested within the product-cycle model.

Testing the validity of linear restrictions in nested models involves testing the assumption that the restrictions imposed on the general model are correct. That is, we test the joint hypothesis that the set of linear restrictions cannot be rejected at a given level of significance. Under the assumption that the null hypothesis is correct, for n observations and k estimated parameters in a linear regression model with a normally distributed error term, g linear restrictions can be jointly tested using an F -test with $F(g, n - k)$ degrees of freedom:

$$F(g, n - k) = \frac{(r_0 - r)(n - k)}{gr}, \quad (3)$$

where r_0 is the residual sum of squares of the restricted model, and r is the residual sum of squares in the unrestricted (general) model (Maddala, 1988). Most contemporary econometrics software packages employ a suite of both nested and nonnested tests. Our empirical analysis has been conducted using PcGive 9.0 (Hendry and Doornik, 1996).

3 Model validation and testing

The dynamics of regional unemployment for Australia between 1984 and 1992 are summarized in table 2 and figure 1 (over). During this period, average unemployment across Australia's regional economies ranged from about 6.5% in 1989 to 10.6% in 1992. From 1984 to 1988 the average unemployment rate remained relatively stable between about 8.1% and 8.6% during a period of economic buoyancy. In some regions, much higher levels of unemployment persisted where their structures predisposed their communities to higher levels of unemployment, or where there was insufficient resilience to accommodate the impact of structural change (Taylor, 1992). During the period between 1989 and 1992, as the Australian economy slipped into recession, the average unemployment rate was more volatile, first falling to around 6.5% and subsequently rising to around 10.6% in 1992. Casual empiricism suggests that, with the exception of 1988, the Australian economy experienced diverging employment rates between regions when the average unemployment rate was either stable or falling. Regional differentiation, as measured by the coefficient of variation, became more volatile during the 1990s. During 1991 and 1992, when unemployment rates began to rise, there appears to have been some convergence between regional unemployment rates. Areas of formerly low unemployment, especially in Melbourne and Sydney, and in the coastal retirement and lifestyle areas of northern New South Wales and southeast Queensland, began to experience high levels of unemployment (Taylor, 1992).

However, casual empiricism should be treated with caution. The time period under consideration is relatively short and our measure of regional differentiation may be sensitive to a number of extreme values in each year. For example, for seven of the nine years, Hervey Bay, a retirement and lifestyle locality on the southern Queensland coast, had an unemployment rate that was significantly higher than the average across Australia's regions. In the other two years, the highest unemployment rates were

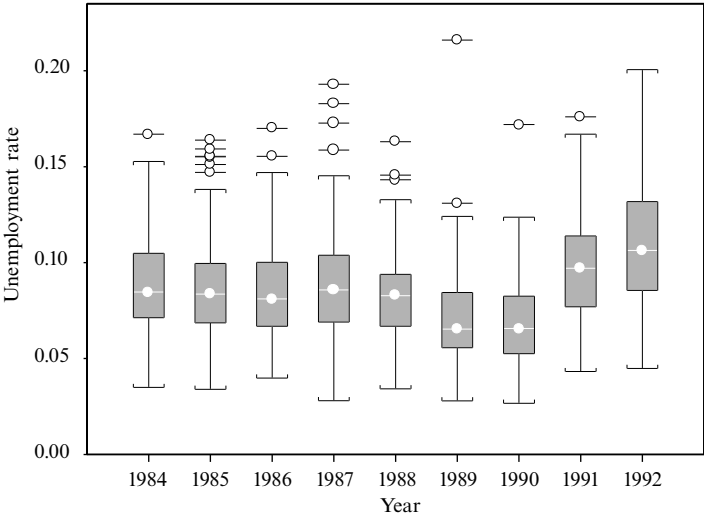


Figure 1. Unemployment dynamics, 1984–92.

Table 2. Unemployment statistics, 1984–92.

	1984	1985	1986	1987	1988	1989	1990	1991	1992
Mean	0.085	0.084	0.081	0.086	0.083	0.065	0.066	0.099	0.106
Median	0.089	0.088	0.086	0.090	0.084	0.072	0.071	0.098	0.109
Interquartile range	0.034	0.031	0.038	0.038	0.027	0.029	0.030	0.037	0.046
Standard deviation	0.026	0.029	0.029	0.031	0.025	0.028	0.026	0.026	0.030
Coefficient of variation	0.291	0.323	0.332	0.342	0.294	0.384	0.371	0.269	0.275

recorded at Coffs Harbour (1985), also a coastal retirement and lifestyle locality in northern New South Wales, and Mandurah (1991), a similar coastal center south of Perth in Western Australia. Although not as extreme, throughout this period the lowest unemployment rates were recorded in the affluent suburbs of the Northern Sydney region and the West Australian wheat belt center of Narragin, a rural center that exports its unemployment to the cities like many other rural centers.

From the unemployment relativities for 1984 and 1992, the general model specification is as shown in table 3. In the general model specification, the set of explanatory variables accounts for 61.5% of the variability in unemployment relativities between regions in 1992. A computed $F(9,82) = 14.528$ provides strong evidence in favor of the hypothesis that this set of predictor variables accounts for a statistically significant amount of the variability in this model. The mean reversion in unemployment rates between 1984 and 1992 is equal to 0.24, which is statistically significantly different from unity at the 1% significance level [$H_0: \beta_1 = 1; \chi^2_{(1)} = 57.266, p = 0.000$]. That is, there is evidence in the sample to suggest that there is conditional mean reversion or convergence in unemployment relativities between the regions in the period 1984–92.

From the set of regionally specific structural variables only two, *S* and *D*, are statistically significant and have signs that are consistent with our theoretical expectations. Those regions with higher levels of local specialization (*S*) have lower estimated unemployment relativities. Similarly, those regions with a better human resource base (*D*), as measured by lower percentages of the working population without a degree, are predicted to have lower relative unemployment rates. More controversially, those

Table 3. General model specification.

Variable	Coefficient	Standard error	<i>t</i> -value	<i>t</i> -probability
β_0	-0.924	0.306	-3.023	0.003**
$\ln(R_{it-\tau})$	0.240	0.100	2.391	0.019*
<i>T</i>	-0.051	0.045	-1.131	0.262
<i>I</i>	-0.027	0.032	-0.824	0.412
<i>M</i>	0.001	0.008	0.067	0.947
<i>P</i>	0.021	0.007	3.026	0.003**
<i>D</i>	0.022	0.005	4.702	0.000**
<i>C</i>	0.005	0.013	0.390	0.697
<i>A</i>	0.030	0.027	1.087	0.280
<i>S</i>	-0.948	0.280	-3.381	0.001**

$R^2 = 0.615, F(9, 82) = 14.528$ [0.000]**

<i>MC</i>	<i>Z</i>	=	1.953 [0.051]
Normality	$\chi^2(2)$	=	7.293 [0.026]*
X_i^2	$F(18, 63)$	=	0.929 [0.548]
$X_i * X_j$	$F(54, 27)$	=	0.938 [0.591]
RESET	$F(1, 81)$	=	1.288 [0.260]

Key:
MC denotes Moran’s I test for first-order spatial autocorrelation in the errors. The null hypothesis is no spatial autocorrelation.
 X_i^2 tests if the errors have constant variances against the alternative that the squared errors depend on the original and squared regressors. The null hypothesis is no heteroskedasticity.
 $X_i * X_j$ checks if homoskedasticity is reasonable against the squares error depending on cross products of the regressors. The null hypothesis is no heteroskedasticity.
RESET denotes the Ramsey functional form misspecification test. The null hypothesis is no functional form misspecification.
[...] Probabilities.
*denotes significances at the 5% level.
**denotes significances at the 1% level.

regions with higher levels of institutional thickness, as measured by the effective rate of protection (*P*), are predicted to have higher unemployment relativities. Thus, although local sectoral specialization and the quality of the local human resource base appear to generate job growth in the Australian context, institutional thickness (measured here in terms of protection), which has been postulated as essential to local social-capital formation and the generation of sustainable local growth, is at best irrelevant and at worst counterproductive.

The remaining variables are not individually significant, although, with the exception of *C* and *A*, they do have signs that are consistent with our theoretical specification. It is, however, surprising that the variable intended to capture the extent of local knowledge creation and access to information in a place, *I*, is not statistically significant, suggesting that access to information as part of local learning processes might have been overplayed in the ‘soft’ models of local growth. Reinforcing this view of local learning processes is the positive but again statistically insignificant stimulus to local job growth provided by the local (locational) integration of business enterprises (*M*). Adding to this interpretation, higher levels of technological leadership at the enterprise level (*T*), a key element in ‘soft’ theoretical models of local growth, is also not individually statistically significant in the present analysis, though it does have a sign consistent with expectations. This is a particularly important finding in relation to the role of high-tech industry in local growth processes. Not only is this sector pivotal in models of local growth, it lies at the heart of economic growth policies, not least in

Australia. To suggest that high-tech industry plays a minor, though positive, role in local growth processes and in important aspects of local learning processes suggests that theory-driven policies which emphasize high-tech industry and learning as the basis of local social-capital formation might benefit from careful reassessment.

Controversially, greater openness to interregional trade, measured here as access to intermediate markets (4), is associated with higher rates of regional unemployment. The variable is not individually significant in the model, but the direction of the relationship is completely at odds with what the competitive-advantage and product-cycle models propose. Also at odds with expectations, and in this instance in relation to the role of propulsive industries postulated in the growth-pole model, unemployment relativities are predicted to be higher in regions where the power of large corporations to affect structure and strategy (C) is higher. This is, however, consistent with the expectations of the segmentation model. It suggests that the local embeddedness of large corporations, including the embeddedness of transnational corporations that has been proposed by, for example, Dicken et al (1994) and Yeung (1998) as part of local learning and local growth processes, might be more apparent than real when it is combined with other processes in the particular spatiotemporal context of the Australian analysis presented here.

It must be emphasized, moreover, that the interpretation and significance both of the parameter estimates and of the overall model are only meaningful if our specification satisfies the assumptions underlying OLS estimation. On the basis of the set of diagnostic tests (table 2), there is no evidence in the sample to suggest that the disturbance term is spatially autocorrelated, has nonconstant variance (heteroskedasticity), or has functional form misspecification. However, our test of normality in the disturbance term does indicate the presence of nonnormality at the 5% significance level.

A visual inspection of a set of standard plots of the disturbance term supports the results of the diagnostic tests (figure 2). The plots of residuals versus predicted values fails to identify any systematic variability in the disturbance term that might suggest an

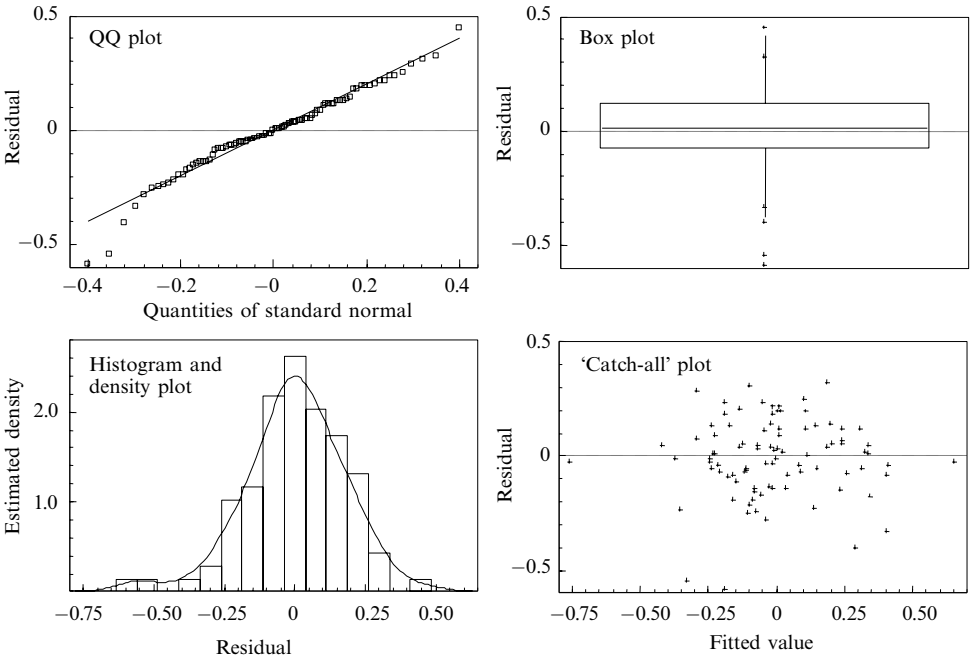


Figure 2. Diagnostic plots for the general model.

incorrectly specified model. In addition, the cross-probability plot (QQ plot) of observed against expected values for a normal distribution, and a density plot comparing a histogram of the observed values against a normal density plot, suggest that nonnormality may be caused by the presence of outlying values. In accordance with existing conventions, an outlying value is defined as a residual that lies one step outside of the interquartile range, where a step is defined as $1.5 \times$ interquartile range of the distribution of residual variation (Erickson and Nosanchuk, 1992; Hamilton, 1992). In this instance, the box plot of residuals identifies a small number of residuals that are potential outliers. However, only Alice Springs and Horsham have residual values that lie well beyond the one-step rule of thumb for identifying an outlying value. Specifically, our general model significantly underpredicts unemployment relativities for Alice Springs and Horsham. These values should be flagged as a potential data issue. That Alice Springs might be a data outlier is, to some extent, to be expected. It is an isolated region in which Federal and Territory government intervention has been extensive, and where market mechanisms are minimal. The Horsham outlier may, in part, relate to the waning importance of the textile, clothing, and footwear industries that had developed in regional centers, especially in Victoria, on the sites of former munitions plants. Although there is no clear theoretical justification for omitting these values, we computed the model excluding these observations (table 4).

On the basis of the set of diagnostic tests, removing the two outlying observations corrects for the nonnormal disturbance in the general model (figure 3, over). Specifically, the plot of residuals versus predicted values fails to identify any systematic variability in the disturbance term that might suggest an incorrectly specified model. The cross-probability plot (QQ plot) and the density plot suggest that excluding Alice Springs and Horsham has corrected for the nonnormality that existed in the initial model specification. Further, omitting these observations does not appear to impact negatively either upon the overall significance of the model or on the significance of the individual parameter estimates. More troubling is that the sign of M has changed, predicting that higher levels of local integration among small firms will result in lower

Table 4. General model specification, excluding outliers.

Variable	Coefficient	Standard error	<i>t</i> -value	<i>t</i> -probability
β_0	-0.526	0.276	-1.905	0.060
$\ln(R_{it-t})$	0.362	0.090	4.019	0.000**
T	-0.050	0.039	-1.265	0.210
I	-0.045	0.028	-1.603	0.113
M	-0.003	0.007	-0.382	0.704
P	0.021	0.006	3.519	0.001**
D	0.014	0.004	3.259	0.002**
C	0.004	0.011	0.387	0.700
A	0.020	0.024	0.851	0.397
S	-0.707	0.249	-2.836	0.006**

$R^2 = 0.652, F(9, 80) = 16.685 [0.000]**$

MC	Z	$=$	1.088 [0.277]
Normality	$\chi^2(2)$	$=$	0.234 [0.890]
X_i^2	$F(18, 61)$	$=$	1.591 [0.091]
$X_i * X_j$	$F(54, 25)$	$=$	1.065 [0.445]
RESET	$F(1, 79)$	$=$	0.600 [0.441]

Key: see table 3.

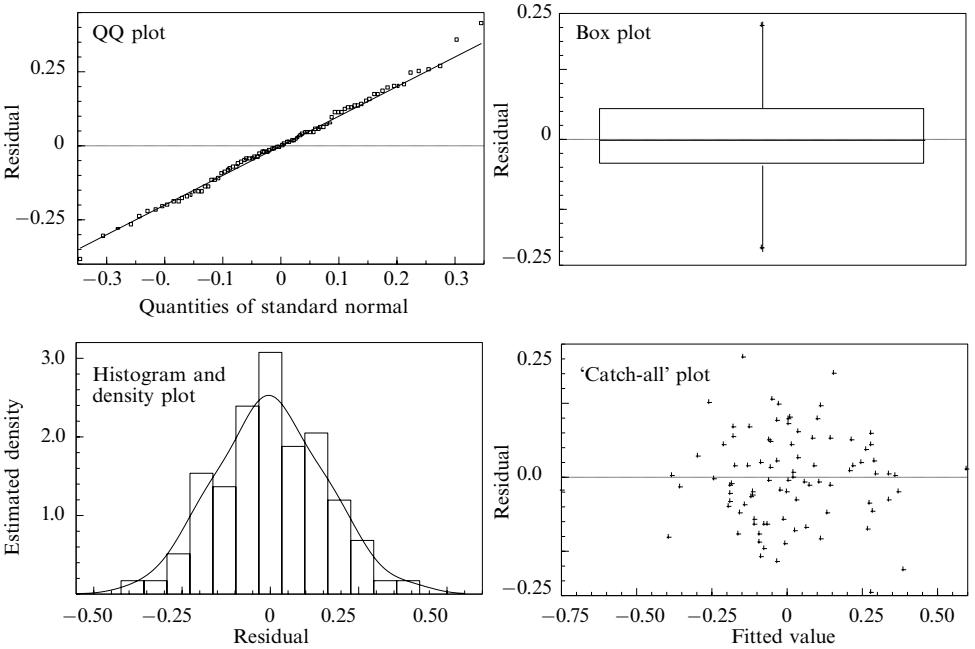


Figure 3. Diagnostic plots for the general model, excluding outliers.

unemployment relativities. However, for both models, this parameter estimate is not individually statistically significant.

Overall, because the general model appears to fit the Australian data reasonably well, is statistically significant, and the diagnostic tests do not reveal any significant misspecification issues, we feel justified in using the general model to evaluate the alternative specification to the ‘soft’ theoretical models of local growth. However, in light of the results of fitting the general model with and without the outlying values, we propose to test the validity of the competing theoretical models against our general model specification, reporting the results of the encompassing procedure both for the full and for the reduced samples (see table 5).

For both the full and the reduced sample cases, there is evidence to suggest that we can reject the assumption that the set of linear restrictions imposed on the general model by the product-cycle model, the growth-pole model, and the segmentation model are correct. In contrast, the evidence suggests that the restrictions imposed on the general model by the competitive-advantage model and the learning-regions model are correct. The set of linear restrictions imposed by the flexible-specialization model is more ambiguous, being rejected for the full sample but not for the reduced sample. On the basis of variance encompassing we can, therefore, reject the growth-pole, product-cycle, and segmentation models of local growth in favor of the general model. In contrast, we can reject the general model in favor of the competitive-advantage model, the learning-regions model, and the flexible-specialization model. In addition, since the learning-regions model and the flexible-specialization model are nested within the competitive-advantage model, we can employ the same variance-encompassing logic to compare these ‘soft’ models. There is evidence in the sample to suggest that we can reject the assumption that the linear restrictions imposed on the competitive-advantage model by the flexible-specialization model are correct [full sample $F(3,83) = 4.15^{**}$, reduced sample $F(3,81) = 3.21^{*}$]. In contrast, the evidence suggests that the restrictions imposed on the general model by the learning-regions model are correct [full sample

Table 5. Testing linear restrictions on the general model.

Theoretical model	Full sample	Outliers removed
Competitive advantage	$F(1, 82) = 0.15$	$F(1, 80) = 0.15$
Learning regions	$F(2, 82) = 0.75$	$F(2, 80) = 0.50$
Flexible specialization	$F(4, 82) = 3.12^*$	$F(4, 80) = 2.42$
Product cycle	$F(3, 82) = 8.80^{**}$	$F(3, 80) = 8.27^{**}$
Growth pole	$F(5, 82) = 9.03^{**}$	$F(5, 80) = 7.47^{**}$
Segmentation	$F(5, 82) = 8.74^{**}$	$F(5, 80) = 7.00^{**}$

*denotes significance at the 5% level.

**denotes significance at the 1% level.

$F(1, 83) = 1.37$, reduced sample $F(1, 81) = 0.87]$. Further, the learning-regions model variance dominates the flexible-specialization model [full sample $F(1, 84) = 5.52^{**}$, reduced sample $F(1, 84) = 7.72^{**}]$. That is, based upon the evidence from Australia’s regional economies between 1984 and 1992, the learning-regions model variance dominates both the general model and the flexible-specialization model. In accordance with our model-selection criterion, we conclude that the learning-regions model is the encompassing model. Table 6 (see over) summarizes the learning-regions model for the full sample and with outliers removed. Both the model specification and the diagnostics are consistent with the results derived from the general model. Accordingly, parameter estimates in the learning-regions model are subject to the same interpretation and caveats as for the general model. For Australia between 1984 and 1992, therefore:

- (a) sectoral specialization and the human-resource base enhanced local job growth;
- (b) institutional thickness restricted rather than enhanced local job growth;
- (c) high-tech industry and information access enhanced local growth but only in a minor way; and
- (d) the local integration of enterprises was ambiguous in its impact and was no more than a minor force impacting on local job growth.

4 Conclusions

What we have attempted in this paper is to test empirically in a preliminary way the usefulness of six theoretical models of local economic growth for explaining the dynamics of regional unemployment in Australia for the period 1984–92. From the theoretical models, eight broad dimensions representing the hypothesized drivers of local economic change have been derived which, through surrogate measures, have been incorporated into an empirical modeling process. A general model was developed within which the dimensions derived for the competing theoretical models were nested.

The results of the empirical modeling process are clear and revealing, but must be interpreted with some caution. First, all the models offer only partial explanations of regional job growth in Australia during the study period, with each refining and elaborating different subsets of processes. Given the validity of the model specifications, there are two possible inferences to be drawn from this finding: either the models individually overly elaborate particular local growth processes; or the processes they encompass do not operate in Australia in the manner postulated. In either case, the ‘soft models’ need refining. Equally, however, the model specification may fail to capture fully the nuanced processes of the ‘soft’ models, calling for refinement of the modeling process.

Second, the most broadly supported theoretical model is the learning-regions model, at least as it has been specified here. However, significant elements of that

Table 6. The learning-regions model.

Variable	Coefficient	Standard error	<i>t</i> -value	<i>t</i> -probability
(a) <i>Full sample</i>				
β_0	-0.962	0.298	-3.229	0.002**
$\ln(R_{it-\tau})$	0.247	0.099	2.481	0.015*
<i>T</i>	-0.040	0.044	-0.912	0.364
<i>I</i>	-0.006	0.027	-0.214	0.831
<i>M</i>	0.002	0.007	0.267	0.790
<i>P</i>	0.025	0.006	4.186	0.000**
<i>D</i>	0.022	0.005	4.707	0.000**
<i>S</i>	-0.896	0.270	-3.316	0.001**
$R^2 = 0.607, F(7, 84) = 18.573 [0.000]**$				
<i>MC</i>	<i>Z</i>	=	1.953 [0.503]	
Normality	$\chi^2(2)$	=	7.381 [0.025]*	
X_i^2	<i>F</i> (14, 69)	=	1.344 [0.205]	
$X_i * X_j$	<i>F</i> (35, 48)	=	1.358 [0.161]	
RESET	<i>F</i> (1, 83)	=	0.522 [0.472]	
(b) <i>Outliers removed</i>				
β_0	-0.549	0.269	-2.044	0.044*
$\ln(R_{it-\tau})$	0.369	0.089	4.151	0.000**
<i>T</i>	-0.042	0.038	-1.103	0.273
<i>I</i>	-0.031	0.024	-1.278	0.205
<i>M</i>	-0.001	0.006	-0.231	0.818
<i>P</i>	0.024	0.005	4.576	0.000**
<i>D</i>	0.014	0.004	3.251	0.002**
<i>S</i>	-0.666	0.239	-2.780	0.007**
$R^2 = 0.648, F(7, 82) = 21.569 [0.000]**$				
<i>MC</i>	<i>Z</i>	=	1.205 [0.228]	
Normality	$\chi^2(2)$	=	0.420 [0.811]	
X_i^2	<i>F</i> (14, 67)	=	1.764 [0.063]	
$X_i * X_j$	<i>F</i> (35, 46)	=	0.953 [0.555]	
RESET	<i>F</i> (1, 81)	=	0.248 [0.620]	
Key: see table 3.				

theory find little support in the empirical Australian situation. Locational integration and access to information are central to learning processes and the functioning of Schumpeterian regional innovation systems but, although these do impact on regional growth in Australia in the manner expected, that impact is surprisingly weak. Third, extending this interpretation, the models developed in the paper identify a common set of processes lying at the heart of local economic growth. A degree of technological leadership at the local level is coupled with a strong human-resource base and sectoral specialization, together with the previously identified elements of a local learning process. What this combination of processes suggests is the importance of an ‘enterprise culture’ at the core of local economic growth, which is based more on local human resources than on an elaborate learning process. The question that must be asked is whether it is this human-resource base and ‘enterprise culture’ that needs to be more fully elaborated before we can come to grips with local growth. In this context it might be important to examine more closely local processes of coalition formation among local entrepreneurs as they promote enterprise and create enterprises (see Taylor, 1999). Fourth, further refining this point, information access as a mechanism

for knowledge creation, plus institutional support and institutional thickness, appear to be at best insignificant drivers of local job growth, and at worst even undermine it. This empirical finding places a further major caveat on the currently popular learning-regions, milieu, and flexible-specialization models of local economic dynamics.

It is possible, nevertheless, that the specification of the models used here, and the nature of the surrogates that have been used might have overplayed human resources and underplayed learning, and misspecified mechanisms of knowledge creation and institutional support. Such biases could have preconditioned the results, and call for refinement of the modeling process. Equally, they call for the elaboration of clearer and more testable propositions in 'soft' theories of local economic growth. Indeed, the vagueness of propositions such as 'institutional thickness' and 'social capital', both of which can apparently foster and stifle local growth, is a case in point.

Obviously, the results of this study are exploratory and tentative. Explanatory variables need to be refined and growth needs to be more fully specified to include investment growth and new firm formation as well as job growth and unemployment. Nevertheless, the questions raised by the analyses suggest that, as theory building continues apace in economic geography, the need for the rigorous empirical testing of those theories becomes more urgent.

Clark (1998) has suggested that to improve understanding of the processes shaping the economic geography of a globalizing world requires the econometric rigor employed in models built on stylized facts to interface with the conceptual innovation of 'close dialogue' approaches to the building of 'soft' models of local growth. The analyses reported in this paper are a first attempt to provide such an interface. They suggest, however, that great care needs to be exercised in building grand schemes of explanation, especially the rapidly elaborating 'soft' models centered on learning and social capital, without testing them against empirical examples that have not been selected on the dependent variable (Staber, 1996). They also suggest that great care needs to be taken in specification and measurement when attempts are made to link theory and empiricism.

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References

- Amemiya T, 1985 *Advanced Econometrics* (Harvard University Press, Cambridge, MA)
- Armstrong H, Vickerman R (Eds), 1995 *Convergence and Divergence Among European Regions* (Pion, London)
- Baddeley M, Martin R, Tylor P, 1998, "European regional unemployment disparities: convergence or persistence?" *European Urban and Regional Studies* **5** 195–215
- Blanchard O, Katz L, 1992, "Regional evolutions" *Brookings Papers in Economic Activity* **1** 1–75
- Chalmers A F, 1987 *What is this Thing Called Science?* (University of Queensland Press, New York)
- Charemza W W, Deadman D F, 1997 *New Directions in Econometric Practice* (Edward Elgar, Cheltenham, Glos)
- Clark G, 1998, "Stylized facts and close dialogue: methodology in economic geography" *Annals of the Association of American Geographers* **88** 73–87
- Darnell A C, Evans J L, 1990 *The Limits of Econometrics* (Edward Elgar, Cheltenham, Glos)
- Dhammika D, McAleer M, 1996, "Econometric methodology and the philosophy of science" *Journal of Statistical Planning and Inference* **49** 9–37
- Dicken P, Forsgren M, Malmberg A, 1994, "The local embeddedness of transnational corporations", in *Globalization, Institutions and Regional Development in Europe* Eds A Amin, N Thrift (Oxford University Press, Oxford) pp 23–45
- Erickson B H, Nosanchuk T A, 1992 *Understanding Data* (University of Toronto Press, Toronto)
- Fingleton B, 1999, "Estimates of time to economic convergence: an analysis of regions of the European Union" *International Regional Science Review* **22** 5–35

- Hamilton L C, 1992 *Regression with Graphics* (Duxbury Press, Pacific Grove, CA)
- Hendry D, 1995 *Dynamic Econometrics* (Oxford University Press, Oxford)
- Hendry D F, Doornik J A, 1996 *Empirical Econometric Modelling Using PcGive 9.0* (International Thomson Business Press, London)
- Hendry D F, Mizon G E, 1990, "Procrustean econometrics: or stretching and squeezing data", in *Modelling Economic Series: Readings in Econometric Methodology* Ed. C W J Granger (Oxford University Press, Oxford) pp 121–136
- Hepple L, 1996, "Directions and opportunities in spatial econometrics", in *Spatial Analysis: Modelling in a G.I.S. Environment* Eds P Longely, M Batty (John Wiley, New York) pp 231–246
- Kennedy P, 1992 *A Guide to Econometrics* (MIT Press, Cambridge, MA)
- Laudan L, 1990 *Science and Relativism: Some Key Controversies in the Philosophy of Science* (University of Chicago Press, Chicago, IL)
- McAleer M, 1994, "Sherlock Holmes and the Search for Truth: a diagnostic tale" *Journal of Economic Surveys* **8** 317–370
- Maddala G S, 1988 *Introduction to Econometrics* (Macmillan, New York)
- Martin R, 2000, "EMU versus the regions? Regional convergence and divergence in Euroland" *Journal of Economic Geography* (forthcoming)
- Martin R, Sunley P, 1998, "Slow convergence? New endogenous growth theory and regional development" *Economic Geography* **74** 201–227
- Morgan M, 1988, "Finding a satisfactory empirical model", in *The Popperian Legacy in Economics* Ed. N De Marchi (Cambridge University Press, Cambridge) pp 199–211
- Plummer P, 2000, "The modelling tradition", in *A Companion to Economic Geography* Eds E Sheppard, T Barnes (Blackwell, London)
- Plummer P, Taylor M, 2001, "Theories of local economic growth: concepts, models, and measurement" *Environment and Planning A* **33** 219–236
- Quah D, 1993, "Empirical cross-section dynamics in economic growth" *European Economic Review* **40** 1325–1352
- Sala-i-Martin X, 1996, "The classical approach to convergence analysis" *The Economic Journal* **106** 1019–1036
- Spanos A, 1990, "Towards a unifying methodological framework for econometric modelling", in *Modelling Economic Series: Readings in Econometric Methodology* Ed. C W J Granger (Oxford University Press, Oxford) pp 335–369
- Staber U, 1996, "Accounting for differences in the performance of industrial districts" *International Journal of Urban and Regional Research* **20** 299–316
- Taylor M, 1992, "Labor market change and the regional pattern of unemployment in Australia", working paper, Office of Local Government, Canberra
- Taylor M, 1999, "The small firm as a temporary coalition" *Entrepreneurship and Regional Development* **5** 1–19
- Valdes B, 1999 *Economic Growth: Theory, Empirics and Policy* (Edward Elgar, Cheltenham, Glos)
- Yeung H W-C, 1998, "Capital, state and space: contesting the borderless world" *Transactions of the Institute of British Geographers, New Series* **23** 291–309