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Income convergence across Canadian provinces in the 20th century: Almost but not quite there

Joseph DeJuan[1], Marc Tomljanovich[2]

[1]Department of Economics, University of Waterloo, Waterloo, Ontario, N2L-3G1, Canada
(e-mail: jdejuan@uwaterloo.ca)
[2]Department of Economics, Colgate University, Hamilton, 13346, New York, USA
(e-mail: mtomljanovich@mail.colgate.edu)

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Abstract. There exists uncertainty on both theoretical and empirical fronts regarding Solow's (1956) predictions of income convergence across similar economies. We utilize recently developed time series techniques to examine the convergence characteristics of Canadian provinces between 1926 and 1996. Using personal income data, we find support for both stochastic convergence and β-convergence for the majority of Canadian provinces, after allowing for a structural break in the data. Our results therefore suggest that true economic convergence is occurring for the most part, though significant differences in income still remain. Studying the convergence properties of earnings, we find that governmental redistribution programs are hastening the trend towards convergence for personal income. Finally, the Atlantic and Plains provinces are found to display stronger convergence properties within their regions than Canada as a whole.

JEL classification: C32, O40, R10

1. Introduction

Recent years have witnessed a resurgence of research on issues relating to economic growth. Much of this research has been interested in determining whether or not economies are converging over time to a common level of per capita income. The idea of convergence derives from Solow's (1956) neoclassical growth model which posits that economies with similar preferences and technology should tend to converge to a common per capita income level as a consequence of diminishing marginal returns to reproducible capital. By contrast, the new endogenous growth model initiated by Romer (1986, 1990), Lucas (1988), and Aghion and Howitt (1992) argues that positive externalities

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associated with inputs such as technology and education can lead to increasing returns to scale and, in turn, prevent any tendency towards convergence.

Most of the empirical work on convergence has been carried out using cross-section regressions that relate the initial per capita income level for a group of economies to their subsequent per capita income growth rates. A significantly negative relationship is taken as evidence of convergence as it implies that poor economies are growing faster than rich ones, until ultimately per capita income differences are eliminated. This is known in the literature as β-convergence. Using annual data from seventy-two countries over the period 1950–1990, Baumol (1986) finds that while convergence does not hold across countries as a whole, it does arise within a relatively homogeneous groups of countries such as among the industrial and middle income countries. Subsequent studies by Barro (1991) and Mankiw et al. (1992), among others, find evidence of convergence across a large cross-section of countries, but only after controlling for factors such as savings rates, population growth rates, and education, i.e., *conditional* β-convergence. Barro and Sala-i-Martin (1991) extend the empirical evidence on convergence across the U.S. states, Japanese prefectures, and Western European regions. Their results indicate that convergence has typically proceeded across states/regions within countries at an approximate rate of 2 percent per year. Similar results have been obtained in other regional studies such as Cashin (1995) for Australian states, Hofer and Worgotter (1997) for Austrian regions, Coulombe and Lee (1995) for Canadian provinces, Kangasharju (1998) for Finland regions, Persson (1997) for Swedish counties, and Funke and Strulik (1999) for West German *Lander*. By contrast, other studies have not found support for the convergence hypothesis. For example, Mauro and Podrecca (1994) find no evidence of convergence across Italian regions, but instead find a dual process of development between northern and southern Italy. Chatterji and Dewhurst (1996) and Siriopoulos and Asteriou (1998) also report similar economic dualism across regions in the U.K. and Greece respectively. Button and Pentecost (1995), in a study of fifty-four European Union regional economies, conclude that convergence has not taken place across those economies in the 1980s.

While most of the empirical work has been concerned with the cross-sectional notion of convergence, a time series notion of convergence has also been examined in a number of recent papers. In particular, Carlino and Mills (1993) define stochastic convergence as when the per capita income of one region relative to that of the economy as a whole is stationary. They argue that both stochastic convergence and β-convergence are required for actual convergence to occur. In other words, not only should shocks to relative per capita income be temporary, but also regions with above-average per capita initial incomes should exhibit slower growth than those with below-average initial per capita incomes. Using annual data from eight U.S. regions over the period 1929–1990, they report that the unit root hypothesis cannot be rejected for the relative per capita income for any region and hence, find no support for stochastic convergence. However, when they include an exogenously determined trend break into the tests, the unit root hypothesis can be rejected in three of the eight regions. Moreover, they find β-convergence for the same three regions, indicating that parts of the U.S. are converging. Subsequently, Loewy and Papell (1996) confirm and strengthen Carlino and Mills' results on stochastic convergence by using unit root tests that endogenize both the trend break date and the lag length. More recently, Tomljanovich and Vogelsang (2002) extend Carlino and Mills' work by testing for both stochastic convergence and β-convergence, and conclude that there is strong evidence for U.S. regional income convergence.

In this paper, we utilize recently developed time series techniques to examine the convergence characteristics of ten Canadian provinces over a relatively long time period, 1926–1996. Most previous studies bearing on the existence of convergence within Canada have used cross-sectional methods of testing for convergence.[1] Indeed, we are aware of only one published attempt that uses time series methods. Afxentiou and Serletis (1998) employ a cointegration approach, finding no evidence supporting cointegration and hence of stochastic convergence, across three groups of provinces (namely, the Western, Atlantic, and "rich" provinces) from 1961 to 1991.

The testing framework adopted in this paper differs from and improves on previous Canadian studies in several ways. First, we use data covering the 1926 to 1996 period, given that time series tests for convergence are known to have relatively more power when using data over a long time span. Second, we examine whether the relative per capita income of each province exhibits stochastic convergence. Third, following Carlino and Mills (1993), we test for β-convergence in provinces that exhibit stochastic convergence to determine which provinces experience actual convergence. To this end, we utilize tests for detecting shifts in the trend function of a univariate time series proposed by Vogelsang (1997, 1998). These tests are particularly attractive in that they are asymptotically valid in the presence of general forms of serial correlation in the data and do not require estimates of the serial correlation parameters. Perhaps more importantly, Vogelsang (1997) notes that the tests have good finite sample power for series with errors that have persistent serial correlation. Also, unlike the cross-section tests, the trend function tests for β-convergence enable us to ascertain not only whether Canada as a whole is converging in per capita income, but also whether each individual province is converging to the national average over time. And unlike using panel data estimation, we need

[1] For instance, Coulombe and Lee (1995) and Coulombe and Day (1999) utilize the Barro and Sala-i-Martin type of cross-section regression to examine β-convergence across Canadian provinces from 1961–1991. Given the limited number of provinces, these studies have divided the 1961–1991 growth period into several shorter sub-periods (such as 10-year spans) in order to increase the number of degrees of freedom available for regression analysis. Their empirical findings reveal that poor provinces tend to grow faster than rich ones in per capita terms, as predicted by the neoclassical growth model. Other studies have explored whether different measures of cross-section income dispersion have decreased over time. Williamson (1965) makes use of weighted coefficient of variation as his measure of income dispersion. He finds that Canada had the highest level of regional income disparities among the industrialized countries in 1950–1961. Chernick (1966) uses unweighted coefficient of variation and reports that income disparities across Canadian provinces had remained relatively constant in 1926–1964. Similar results are reported by McInnis (1968) using three measures of income dispersion, namely the mean deviation from the national income level, relative mean deviation, and relative root-mean-squared deviation. Helliwell (1996) uses unweighted standard deviation and concludes that there was no significant difference in the rate of income convergence between 1926–1960 and 1960–1990.

not impose restrictions concerning common trend functions or error specifications across provinces. Fourth, we compare results using different measures of income, and find that our convergence results, while not changing qualitatively, are measurably impacted by government redistribution programs. Finally, we consider the issue of convergence clubs, as proposed by Baumol (1986), by studying the income convergence properties of neighboring provinces with similar structural characteristics, notably the Atlantic and Plains provinces.

The remainder of the paper is organized as follows. Section 2 provides a preliminary look at the data. Section 3 discusses the trend model tests for β-convergence. Section 4 presents the empirical results. Section 5 concludes the paper.

2. A preliminary look at the data

We begin our analysis by examining the evolution of per capita personal income of each province relative to the Canadian national average during the period 1926–1996.[2] Figure 1 contains plots of the annual time series of the natural logarithm of this variable. For Newfoundland, the time series starts in 1949, the year in which the province joined the Canadian Confederation.

It is apparent in Fig. 1 that British Columbia and Ontario typically had per capita incomes above the national average while the Maritime provinces of New Brunswick, Nova Scotia and Prince Edward Island (PEI) consistently lay below the national average. Alberta, Manitoba, Quebec and Saskatchewan, on the other hand, had per capita incomes at about the national average throughout the period. Note however the sharp year-to-year fluctuations in per capita incomes of the Prairie provinces, particularly in Saskatchewan, where agriculture was the dominant sector of economic activity. Alberta's economy also depended heavily on agricultural products in the early part of the twentieth century so we can observe that its income fluctuations followed a similar pattern as that of Manitoba and Saskatchewan during that period. After the discovery of its massive oil reserves and the rapid expansion of the petroleum industry in the late 1940s, Alberta's per capita income increased and was above the national average, except in years of depressed energy prices. For Newfoundland, it joined Canada in 1949 to become the poorest province and remained so in 1996.

It is also clear in Fig. 1 that in every year of the 1926–1996 period, the range of the cross-section distribution of log relative per capita income is rather wide, indicating the large degree of income disparities among the Canadian provinces. The question of interest is: have income disparities in Canada changed over the past seventy years? In particular, have they shown a tendency to decrease over time? Looking at Fig. 1, the range of the

[2] Personal income is defined as the sum of wages and salaries, accrued net income of farm operators, net income of nonfarm unincorporated business, interest, dividends and other investment incomes, transfer payments from government, corporations and nonresidents. Data for the ten Canadian provinces were collected from the *Provincial Economic Accounts* section of the CANSIM database maintained by *Statistics Canada*. Incomplete data for Northwest Territories, Nunavut and Yukon led us to exclude them from the study.

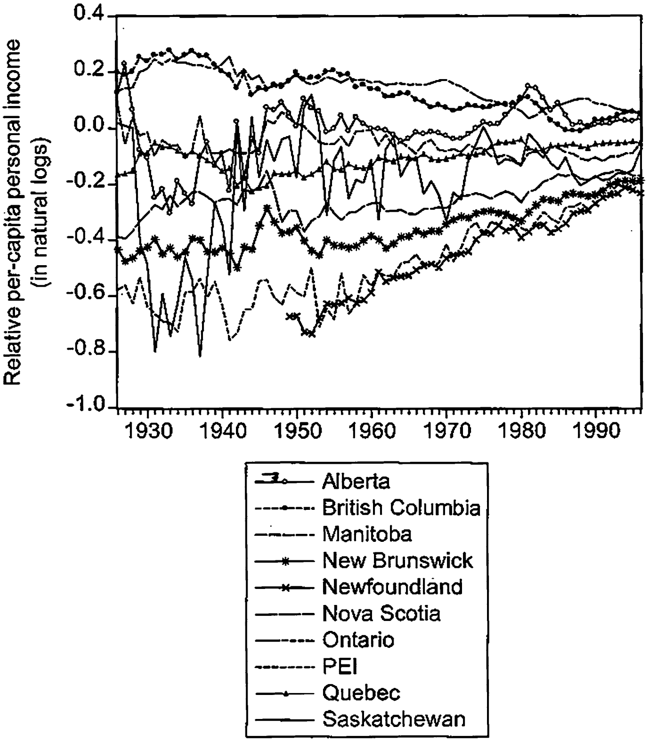

Fig. 1. Canadian provinces

distribution remained fairly stable from 1926 until the late 1940s. Since that time the range has narrowed. For example, Prince Edward Island's per capita income was 57% below national average in 1926 and remained at about the same level in 1946, but the difference narrowed to only 19% in 1996. A similar observation may be made for all of the other Maritime provinces and Quebec. In the case of British Columbia, per capita income was 20% above average in 1926 and remained at the same level in 1946, but this figure had fallen to 5% in 1996. Per capita income in Ontario was 14% above average in 1926, increased slightly to 15% in 1946, and fell to 5% above in 1996. For Alberta, per capita income was 13% above average in 1926, falling to 7% above in 1946, and settled at 4% above in 1996.

Although Fig. 1 seems to show that Canadian provinces as a whole have been converging in per capita income since the late 1940s, further analysis of convergence patterns is warranted. One, we will be able to identify if income convergence has been occurring for all provinces or just a subset of them. Two, we will be able to better determine precisely when this convergence began. Three, the presence of regional or national economic shocks may have altered the relative distribution of Canadian income at some point during the twentieth century. Our research methods will be able to determine if this is the case, and if so, to what extent it impacts the individual provinces. Lastly and perhaps most importantly, Fig. 1 only gives us a rough visual guide as to whether income convergence has been occurring. It tells us nothing about possible reasons for this trend. We consider what role the national government has played in accelerating the rate of regional income convergence.

To provide a summary measure of the trends in income disparities in Canada, we calculate the unweighted cross-sectional standard deviation of log relative provincial per capita incomes for each year.[3] Figure 2 plots the time path of this dispersion index. Consistent with our visual observation of Fig. 1, the index showed no clear tendency to either decrease or increase from 1926 until the late 1940s, implying that there is virtually no evidence of a narrowing in provincial income disparities during this time period. Since then, the index has declined gradually but consistently, from 0.23 in 1946 to 0.10 in 1996. This general downward trend in the index suggests that there is some tendency for provincial per capita income levels to converge towards the national average during the postwar period, a phenomenon noted in the literature as σ-convergence. Note that this convergent trend can be attributed in part to the rise in relative income position of the Atlantic (i.e., Maritimes plus Newfoundland) provinces and partly to the fall in relative income position of British Columbia and Ontario.

When analyzing convergence, it is important to draw distinction between measures of per capita income that include and exclude transfer payments from government. By definition, personal income includes transfer payments. To the extent that transfer payments serve to redistribute income from the "have" to the "have-not" provinces, we expect it to foster convergence across provinces. In order to highlight the role of transfer payments in the convergence process in Canada, we superimpose in Fig. 2 the dispersion index for log relative per capita earned income (i.e., personal income less transfer payments) across provinces.[4] As can be seen, the index based on personal income lies below that of earned income for most of the periods, confirming the widely-held view that government transfer payments do play a role in reducing income disparities across provinces. Moreover, the gap between the two indexes has widened considerably since the 1950s. This is perhaps not too surprising when one considers the fact that increased efforts by the federal government to establish inter-provincial redistribution programs, notably those associated with equalization payments, started in 1957. The subjects of earned income and σ-convergence are further explored in Sect. 4.

3. Trend model test of β-convergence

In this section, we discuss a testing framework for β-convergence based on a linear deterministic trend model which remains valid whether or not a unit root is present in the time series. To begin with, let y_t denote the log of relative per capita income at time t. β-convergence posits that provinces having per

[3] To avoid giving disproportionately more weights to smaller provinces, one may instead use the weighted cross-sectional standard deviation, with weights set equal to the population share in each province. However, we found that both weighted and unweighted standard deviations showed similar time paths. In fact, the correlation between the variables is 0.908. In what follows, we use the unweighted cross-sectional standard deviation as our measure of interprovincial income disparity.

[4] Data on provincial per capita earned incomes are only available from 1926 to 1990.

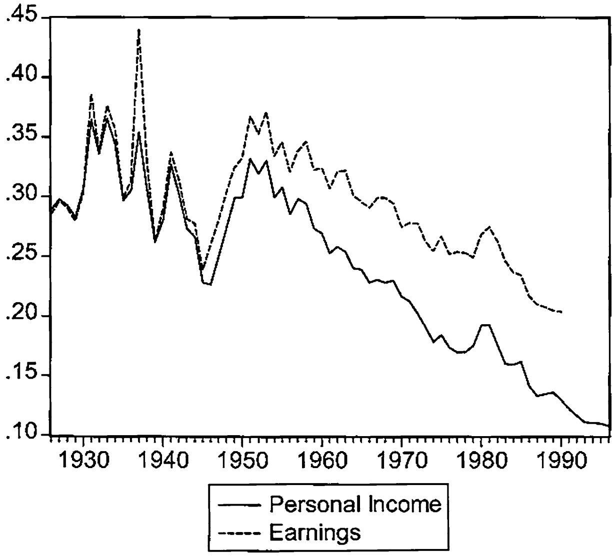

Fig. 2. Dispersion of relative per-capita personal income and earnings across Canadian provinces

capita incomes initially below the national average should exhibit faster growth than those provinces having per capita incomes initially above the national average. These requirements for β-convergence map directly into hypotheses regarding the parameters of the deterministic trend function of y_t. Formally, suppose that y_t is modeled as:

$$y_t = \mu + \beta t + u_t \tag{1}$$

where μ represents the initial level of y_t, β represents the average growth rate of y_t over time, and u_t is a mean zero random process that is serially correlated. β-convergence requires that if $\mu > 0$ then $\beta < 0$, and if $\mu < 0$ then $\beta > 0$. Although μ is not precisely the same as the initial level of relative per capita income, we have found that the differences between the two are statistically insignificant for all ten Canadian provinces. Therefore, evidence on β-convergence can be obtained from estimates of the trend function of y_t.

If u_t is serially uncorrelated, then OLS estimates of μ and β are unbiased and efficient. In practice, however, u_t is likely to be strongly autocorrelated and may be a unit root process. In such case, OLS loses its optimal properties and inference on estimates of μ and β is complicated. The approach taken by some authors to tackle this problem has been to model u_t as an AR(2) process and rewrite y_t as an autoregressive process; see, for example, Carlino and Mills (1993). It is important to note, however, that there are at least three drawbacks to writing y_t in the autoregressive form. First, the trend parameters in the autoregressive representation of y_t are nonlinear functions of μ, β, and the serial correlation parameters. Therefore, obtaining information about μ and β requires untangling this nonlinear relationship which is nontrivial. Second, the AR(2) model may not always provide an adequate approximation to the correlation structure of u_t for all provinces and hence can lead to misspecification. Finally, when u_t is $I(0)$, information about β can be obtained from the estimate of the coefficient on the trend term in the autoregressive representation of y_t. On the other hand, when u_t is $I(1)$, this estimate is not related to β (as the true coefficient becomes zero) and information about β must be obtained from the estimate of the coefficient on the intercept in the autoregressive representation of y_t. Thus, the possibility of a unit root in u_t can cloud the interpretation of the point estimates of trend function parameters in the autoregressive representation of y_t.

In this paper, we take a different approach in dealing with the inference problem on μ and β when u_t is serially correlated. Specifically, we utilize a class of statistics recently proposed by Vogelsang (1998) which are valid in the presence of serially correlated errors and can be used without having to estimate the serial correlation parameters, either parametrically or nonparametrically. The statistics are also valid for $I(0)$ or $I(1)$ errors and hence do not require unit root pre-tests. Indeed, this is an important property because, in practice, it is not possible to discriminate efficiently between $I(0)$ or $I(1)$ using conventional unit root or stationarity tests.

The statistics proposed by Vogelsang are based on two simple regressions that are both estimated by OLS. The first regression, the y_t regression, is given by:

$$y_t = \mu_1 DU_{1t} + \beta_1 DT_{1t} + \mu_2 DU_{2t} + \beta_2 DT_{2t} + u_t \tag{2}$$

where $DU_{1t} = 1$ if $t < T_b$ and 0 otherwise; $DU_{2t} = 1$ if $t > T_b$ and 0 otherwise; $DT_{1t} = t$ if $t < T_b$ and 0 otherwise; $DT_{2t} = t - T_b$ if $t > T_b$ and 0 otherwise. T_b denotes the date of a shift in the parameters of the trend function of y_t. T_b is considered either known, or unknown, in which case T_b is estimated from the data. The parameters μ_1 and μ_2 indicate whether relative per capita income is above or below average in periods 1 and T_b, respectively. The parameters β_1 and β_2, on the other hand, are the average growth rates before and after the break.

The second regression is given by:

$$z_t = \mu_1 DT_{1t} + \beta_1 SDT_{1t} + \mu_2 DT_{2t} + \beta_2 SDT_{2t} + S_t \tag{3}$$

where $z_t = \sum_{j=1}^{t} y_j$, $SDT_{it} = \sum_{j=1}^{t} DT_{ij}$, i = 1,2 and $S_t = \sum_{j=1}^{t} u_j$.

Testing for convergence amounts to testing whether the parameters μ_1, μ_2, β_1, and β_2 are different from zero and have signs consistent with convergence. Consequently, all that is needed are tests of the significance of the OLS estimates in the y_t and z_t regressions. Vogelsang (1997) provides statistics that can be used for this purpose. The statistics are simple modifications of standard t-statistics computed by OLS. Let t_y and t_z generically denote the t-statistics for testing the null hypothesis that the individual parameters in the y_t and z_t regressions are zero. For the y_t regression, the appropriate modified t-statistics are simply $T^{-1/2}t_y$, where T is the sample size. For the z_t regression, the appropriate modified t-statistics are defined as $t - PS = T^{-1/2} t_z exp(-bJ_T)$, where b is a constant and J_T is T^{-1} multiplied by the Wald statistic for testing $c_2 = c_3 = \ldots = c_9 = 0$ in the OLS regression:

$$y_t = \mu_1 DU_{1t} + \beta_1 DT_{1t} + \mu_2 DU_{2t} + \beta_2 DT_{2t} + \sum_{j=2}^{9} c_j t^i + u_t \tag{4}$$

Note that the J_T statistic is a unit root statistic proposed by Park and Choi (1988) and Park (1990). J_T can be computed as $(RSS_Y - RSS_J)/RSS_J$, where RSS_Y is the residual sum of squares from regression (2), and RSS_J is the residual sum of squares from regression (4). Given a significance level for the test, b can be chosen so that the critical values of the $t{-}\mathrm{PS_T}$ statistics are the same when u_t is $I(0)$ and when u_t is $I(1)$. Therefore, the J_T modification results in t-tests from the z_t regression that are robust to $I(1)$ errors. If $b=0$, then the J_T modification has no effect. The distribution of $t-PS_T$ is different when u_t is $I(0)$ compared to when u_t is $I(1)$. Use of $b=0$ is appropriate if the errors are known to be $I(0)$ and we are certain that the $I(0)$ asymptotic approximations are more accurate.

The J_T modification is not needed in the y_t regression since the $T^{-1/2}t_y$ statistics have well-defined asymptotic distributions when u_t is $I(1)$. When u_t is $I(0)$, $T^{-1/2}t_y$ converges to zero. Therefore, $T^{-1/2}t_y$ is a conservative test when errors are $I(0)$. As pointed out by Vogelsang (1997), the $T^{-1/2}t_y$ statistics are designed to have power when u_t is $I(1)$, but remain robust when u_t is $I(0)$, while the $t{-}\mathrm{PS_T}$ statistics are designed to have power when u_t is $I(0)$, but remain robust when u_t is $I(1)$. See Vogelsang (1997) for details.

Asymptotic distributions for the $T^{-1/2}t_y$ and $t-PS_T$ statistics are non-standard (nonnormal) and depend on the break date used in the regressions. In particular, the critical values depend on whether the break date is assumed known or unknown. When the break date is assumed unknown, it must be estimated from the data. The method of estimation affects the asymptotic distributions. We use a straightforward method of estimating the break date. First, we estimate the y_t regression sequentially for each break year with 10 percent trimming, i.e., $0.10T < T_b < 0.90T$. For each regression, we then compute T^{-1} multiplied by the Wald statistics for testing the joint hypothesis that $\mu_1=\mu_2$ and $\beta_1=\beta_2$, i.e., the hypothesis that there is no break in the trend function of y_t. The estimated break date is the break date that results in the largest normalized Wald statistic.

The asymptotic distributions of the $T^{-1/2}t_y$ and $t-PS_T$ statistics for both known and unknown T_b follow directly from theorems in Vogelsang (1998). Critical values are tabulated by Vogelsang (1997), which we also report in Tables 2, 3, and 4.

4. Empirical results

Although the trend function tests for β-convergence described in the previous section remain valid whether or not the y_t series is characterized by a unit root, the magnitude of the test statistics are dependent on whether the series is stationary or contains a unit root. For this reason, we begin by examining the time series properties of y_t series for each of the ten Canadian province. In particular, we are interested in determining whether y_t exhibits stochastic convergence. As mentioned earlier, the concept of stochastic convergence is directly related to the unit root hypothesis as it implies that shocks to y_t are temporary and hence, y_t should not have a unit root. To this end, we use the conventional augmented Dickey-Fuller (ADF) test which allows us to test formally the null hypothesis of a unit root against the alternative of trend stationarity.

The results of ADF tests are summarized in Table 1. It is apparent that the null hypothesis of a unit root can be rejected in five provinces (Alberta, British Columbia, Manitoba, Ontario, and Prince Edward Island) at the 5% significance level, and in two additional provinces (Newfoundland and

Table 1. Unit root tests data series: Natural logarithm of relative per-capita personal income

Province	1926–1996		1946–1996	
	ADF t-statistic	ADF lags	ADF t-statistic	ADF lags
Alberta	−4.012**	1	−3.424*	0
British Columbia	−3.608**	3	−3.345*	2
Manitoba	−5.497**	0	−6.259**	4
New Brunswick	−2.999	0	−3.363*	1
Newfoundland	−3.331*	0	−3.331*	0
Nova Scotia	−2.941	0	−3.700**	0
Ontario	−3.815**	0	−3.161*	4
PEI	−4.527**	0	−5.772**	0
Quebec	−2.149	0	−3.975**	0
Saskatchewan	−3.240*	1	−4.907**	0

Notes: ADF is the Augmented Dickey and Fuller test with a data dependent lag length chosen according to the Schwarz information criterion. Critical values for the test are obtained using the response surface method advocated by MacKinnon (1991): −3.166 (10%), −3.476 (5%), and −4.096 (1%). ** and * denote significance at the 5% and 10% level

Saskatchewan) at the 10% level. Furthermore, when restricting the sample to post-World War II, the remaining three provinces (New Brunswick, Nova Scotia, and Quebec), are also found to be stationary at the 10% level. Together these results suggest that stochastic convergence occurred for the majority of Canadian provinces across the entire time span, and for all provinces in post-World War II sample. Thus, the first prerequisite for income convergence, as noted by Carlino and Mills (1993), has been met.

Having found that the log relative per capita personal income of each province exhibits stochastic convergence, we now turn to examine whether β-convergence holds for any of the provinces to make a complete statement on income convergence across Canadian provinces. As discussed earlier, tests for β-convergence amount to testing whether the parameters μ_i and $\beta_i, i = 1, 2$, are significantly different from zero and negatively related. That is, β-convergence implies that if $\mu_1 > 0$ then $\beta_1 < 0$ and if $\mu_2 < 0$ then $\beta_2 > 0$. This negative relation is vital to the analysis because convergence requires initially poor provinces (with a negative intercept) grow at a faster rate than rich provinces (shown by a positive trend point estimate), promoting a catching-up process in levels of per capita income. Two cautionary notes are needed here. One, this methodology offers no predictive power about the future path of relative per capita income levels. Indeed, due to the linear trend specification, *any* statistically significant value of β_i implies divergence at some point in the future for either an initially rich or poor province. This analysis is limited to historical interpolations; hence fitting a linear trend to the provincial data is reasonable. Two, unlike cross-sectional studies of convergence, here there is no speed-of-convergence parameter to estimate. Thus, we cannot say at what future point convergence will be reached for each individual province. However, an alternate discussion of overall convergence speeds across variables occurs in Sect. 4.2.

We estimate both known and unknown trend break date models. The former is estimated with the break date set at 1946, the year often associated with structural shifts in the relative per capita incomes due to the aftermath of World War II. The latter model, on the other hand, by letting the data choose the break date, completely avoids the potential data-mining criticism arising from the choice of break date. As will become clear, using an unknown trend break date model slightly weakens the case for β-convergence in that there are fewer statistically significant point estimates. This reflects in part the greater uncertainty in the model with respect to the break date and consequently the lower power of the tests.

Tables 2 to 5 present the empirical results for both known and unknown break date models. The estimates of μ_i and β_i along with their t-statistics and critical values are given in Tables 2, 3, and 4. Table 5 conveniently summarizes the results of Tables 2 to 4 with respect to convergence. The last column of these tables reports the estimated break year. Apart from Newfoundland, it is instructive to note that the endogenously determined break dates cluster mainly into two groups: one at the beginning and a second just after World War II. The use of 1946 as the known break year may thus be a reasonable assumption for the provinces. For Newfoundland, the break was determined to be around 1979.[5] Table 2 reports the estimation results of the z_t regression. The $t\mathrm{-PS_T}$ statistics are given in parentheses below each point estimate and the asymptotic critical values are given in the bottom two rows. In this table, the J_T correction was not applied when computing the $t - PS_T$ statistics ($b = 0$ was used). Based on the results that we obtained earlier which show that all of the series have stationary errors, the J_T correction may not be needed if the persistence of the errors is such that the $I(0)$ asymptotic approximation is accurate for $t - PS_T$. The results in Table 2 must be viewed with caution, however, given that even stationary errors with realistic persistence could still spuriously inflate the $t - PS_T$ statistics in the sample size with which we are dealing.

In contrast to Table 2, the results presented in Tables 3 and 4 are robust to highly persistent errors. Table 3 contains the same point estimates as in Table 2, but the J_T correction is used. Because of this, the $t - PS_T$ statistics are smaller in magnitude, compared to Table 2, and hence are more conservative in terms of statements about convergence or divergence. We report $t - PS_T$ statistics for 10% and 5% tests in parentheses below each point estimate. Table 4 reports results using the y_t regression and provides the $T^{-1/2}t_y$ statistic below each point estimate.

Table 5 summarizes the results in Tables 2, 3, and 4. A C denotes point estimates consistent with β-convergence that are both statistically significant at least at the 10% level. A c denotes point estimates consistent with β-convergence, but with only one coefficient statistically significant at least at the 10% level. The D and d denote point estimates consistent with divergence, where D signifies both coefficients are statistically significant and d signifies one coefficient is statistically significant. Finally, an E denotes point estimates that are small in magnitude and not statistically different from zero. Such point estimates suggest β-convergence has already occurred.

In Tables 2, 3, and 4, the estimates of per capita income differential in 1926, μ_1, are shown in columns 2 and 6, while the estimates of average annual

5 This break year is essentially at the midpoint of an extended period of transition in Newfoundland's fishing industry, beginning with the introduction of Extended Fisheries Jurisdiction in 1977 (which extended Canadian Jurisdiction over coastal waters to 200 nautical miles from the previous 12 miles) and ending with the multiple bankruptcies that led to the creation of Task Force on Atlantic Fisheries (otherwise known as the Kirby Report) in 1982. For detailed discussion of these issues, see Kirby (1982), Schrank (1995), and Roy (1997).

Table 2. Empirical results using the z_t regression and $t - PS_T$ statistics without J_T correction. Data series: natural logarithm of relative per-capita personal income

Province	Known Break Date: T_b = 1946				Unknown Break Date				
	μ_1	β_1	μ_2	β_2	μ_1	β_1	μ_2	β_1	T_b
Alberta	−0.076	−0141	0.007	0.066	0.220	−5968	−0026	0.132*	1936
	(−0.520)	(−0.094)	(0.092)	(0.222)	(0.838)	(−1.271)	(−0.601)	(0.968)	
British Columbia	0.263**	−0388*	0.194**	−0391**	0.217**	0.322	0.215**	−0362**	1938
	(5.278)	(−0.760)	(7.406)	(−3.813)	(2.285)	(0.219)	(10.448)	(−5.284)	
Manitoba	−0.017	−0.256	−0.003	−0.255**	−0.010	−0.354	−0.001	−0.254**	1945
	(−0.402)	(−0.591)	(−0.134)	(−2.935)	(−0.238)	(−0.809)	(0.041)	(−3.392)	
New Brunswick	−0472**	0.507*	−0460**	0.500**	−0466**	0.383**	−0456**	0.582**	1951
	(−8.027)	(0.840)	(−14.915)	(4.139)	(−21.831)	(2.108)	(−26.439)	(7.682)	
Newfoundland	xxx	xxx	xxx	Xxx	−0726**	1.217**	−0406**	1.194**	1979
					(−102.29)	(22.519)	(−15.710)	(3.938)	
Nova Scotia	−0370**	0.982**	−0348**	0.374**	−0362**	0.862**	−0349**	0.393**	1947
	(−8.936)	(2.310)	(−15.991)	(4.390)	(−10.557)	(2.551)	(−17.708)	(4.964)	
Ontario	0.202**	0.005	0.201**	−0.294**	0.111	1.866	0.231**	−0274**	1933
	(3.759)	(0.010)	(7.118)	(−2.662)	(0.544)	(0.391)	(12.175)	(−4.733)	
PEI	−0620**	−0001	−0672**	0.966**	−0624**	0.029	−0547**	0.929**	1958
	(−11.371)	(−0.001)	(−23.505)	(8.621)	(−27.140)	(0.179)	(−17.131)	(5.520)	
Quebec	−0046**	−0497**	−0167**	0.279**	−0127*	0.304	−0192**	0.294**	1939
	(−1.758)	(−1.115)	(−7.338)	(3.130)	(−2.141)	(0.354)	(−13.145)	(5.937)	
Saskatchewan	−0450**	0.786	−0101	−0125	−0025	−6672*	−0118**	−0055	1938
	(−1.762)	(0.300)	(−0.750)	(−0.238)	(−0.092)	(−1.566)	(−1.982)	(−0.276)	
$I(0)$ 10% cv	±0.854	±0.683	±1.030	±0.908	±1.570	±1.330	±1.140	±0.936	
$I(0)$ 5% cv	±1.120	±0.883	±1.350	±1.200	±2.190	±1.760	±1.500	±1.270	

Notes: ** and * Denote significance at the 5% and 10% level using a one-tailed test. Values in parentheses are the $t - PS_T$ statistics using $b = 0$. The last two rows report the 10% and 5% asymptotic critical values. Newfoundland regression results for $T_b = 1946$ are not possible since Newfoundland became a province only in 1949.

rate of convergence by province during the pre-break period (or 1926–1946), β_1, are shown in columns 3 and 7. With the exception of Alberta, Manitoba and Saskatchewan, the estimates of μ_1 are significantly different from zero which implies that in 1926, per capita income in the other six provinces was significantly different from the national average. In particular, the estimate of μ_1 is positive for British Columbia and Ontario but negative for New Brunswick, Nova Scotia, Prince Edward Island, and Quebec. These results are in concordance with our visual analysis of Fig. 1 that British Columbia and Ontario were the rich provinces in 1926, with initial per capita income above the national average, while the Maritime provinces and Quebec were the poor provinces, with initial per capita income below average. As to the estimates of β_1, they are small in magnitude and statistically insignificant in most provinces. Also, we can see that μ_1 and β_1 are inversely related in only a few cases. Thus, the support for β-convergence is rather weak, indicating that the initially poor provinces had not begun to catch up with the rich ones during the pre-break period.

The estimates of per capita income differential that existed at the beginning of the post-break period (or 1946), μ_2, are shown in columns 4 and 8, while the estimates of the rate of per capita income convergence by province during the post-break period (or 1946–1996), β_2, are shown in columns 5 and 9. Similar to the results in the pre-break period, the estimates of μ_2 are significantly different from zero except in the three Prairie provinces. In contrast to the pre-break period, however, the estimates of β_2 are significantly different from zero for the majority of the provinces. Perhaps more importantly, the results indicate that μ_2 and β_2 are negatively related, implying that β-convergence is occurring in many provinces. Note in particular that Ontario and British Columbia are downwardly convergent provinces. That is, based on the results shown in Tables 3 and 4 under the unknown break date, Ontario's per capita income was 23% above the national average in 1933, but the province had an annual growth rate that was 27.4% below the national average during the 1933–1996 period. For British Columbia, per capita income was 21% above the national average in 1938, but had an annual growth rate that was 33% below the national average in 1938–1996.

On the other hand, the Atlantic provinces and Quebec are upwardly convergent provinces. In New Brunswick, for example, per capita income was 46% below average in 1951, but the province had an annual growth rate that was 58% above average in 1951–1996. Similarly, per capita income in Quebec was 19% below average in 1939, but had an annual growth rate that was 27% above average in 1939–1996.

For Alberta and Saskatchewan, the estimates of μ_2 and β_2 are small and statistically insignificant which imply that these provinces had attained the national per capita income level and per capita income growth rate during the post-break period. In the case of Manitoba, however, per capita income seems to have diverged from the national average (specifically, downwardly divergent) during the 1945–1996 period. Indeed, this result is not apparent from simply studying a single aggregate measure of convergence such as σ-convergence.

Finally, Newfoundland, clearly the poorest province in 1949, exhibited strong convergence before and after the data-chosen break date of 1979, for all possible model specifications and stationarity assumptions.

Table 3. Empirical Results Using the z_t Regression and $t - PS_T$ Statistics with J_T Correction

Province	Known break date: $T_b = 1946$				Unknown break date				
	μ_1	β_1	μ_2	β_2	μ_1	β_1	μ_2	β_2	T_b
Alberta	−0.076	−0.141	0.007	0.066	0.220	−5.968	−0.026	0.132	1936
	(−0.173)	(−0.006)	(0.002)	(0.015)	(0.416)	(−0.215)	(−0.053)	(0.171)	
	(−0.143)	(−0.002)	(0.001)	(0.005)	(0.368)	(−0.103)	(−0.022)	(0.087)	
British Columbia	0.263	− 0.388	0.194	−0.391	0.217	0.322	0.215	−0.362	1938
	(0.786)	(−0.006)	(0.010)	(−0.034)	(0.506)	(0.005)	(0.055)	(−0.126)	
	(0.562)	(−0.001)	(0.001)	(−0.005)	(0.388)	(0.001)	(0.009)	(−0.030)	
Manitoba	−0.017	−0.256	−0.003	-0.255^{*}	−0.010	−0.354	−0.001	-0.254^{**}	1945
	(−0.286)	(−0.249)	(−0.041)	(−1.258)	(−0.183)	(−0.417)	(−0.016)	(−1.773)	
	(−0.269)	(−0.173)	(−0.027)	(−0.905)	(−0.175)	(−0.316)	(−0.012)	(−1.377)	
New Brunswick	-0.472^{**}	0.507	−0.460	0.500	-0.466^{**}	0.383^{*}	-0.456^{**}	0.582^{**}	1951
	(−3.005)	(0.070)	(−0.489)	(0.363)	(−20.336)	(1.761)	(−20.658)	(6.444)	
	(−2.528)	(0.025)	(−0.146)	(0.141)	(−20.084)	(1.634)	(−18.934)	(6.018)	
Newfoundland	xxx	xxx	xxx	xxx	-0.726^{**}	1.217^{**}	-0.406^{**}	1.194^{**}	1979
					(−78.189)	(11.402)	(−6.170)	(2.024)	
					(−74.582)	(8.579)	(−4.435)	(1.562)	
Nova Scotia	-0.370^{**}	0.982	-0.348^{*}	0.374	-0.362^{**}	0.862	-0.349^{**}	0.392^{*}	1947
	(−4.654)	(0.443)	(−1.653)	(0.873)	(−6.990)	(0.898)	(−4.222)	(1.789)	
	(−4.149)	(0.222)	(−0.742)	(0.465)	(−6.502)	(0.580)	(−2.544)	(1.202)	
Ontario	0.202	0.005	0.201	−0.294	0.111	1.866	0.231^{*}	-0.274^{*}	1933
	(0.891)	(0.000)	(0.048)	(−0.075)	(0.292)	(0.081)	(1.399)	(−1.014)	
	(0.692)	(0.000)	(0.008)	(−0.019)	(0.262)	(0.042)	(0.652)	(−0.557)	
PEI	-0.620^{**}	−0.001	-0.672^{**}	0.966^{**}	-0.624^{**}	0.029	-0.547^{**}	0.929^{**}	1958
	(−10.068)	(−0.001)	(−15.395)	(6.379)	(−25.441)	(0.152)	(−13.682)	(4.704)	
	(−9.855)	(−0.001)	(−13.257)	(5.673)	(−25.154)	(0.142)	(−12.638)	(4.420)	
Quebec	−0.076	−0.497	−0.167	0.279	−0.127	0.304	−0.192	0.294	1939
	(−0.222)	(−0.006)	(−0.006)	(0.019)	(−0.901)	(0.040)	(−0.648)	(0.696)	
	(−0.154)	(−0.001)	(−0.000)	(0.003)	(−0.774)	(0.016)	(−0.224)	(0.302)	

Saskatchewan	−0.450	0.786	−0.101	−0.125		−0.025	−6.672	−0.118	−0.055	1938
	(−0.696)	(0.029)	(−0.030)	(−0.024)		(−0.064)	(−0.622)	(−0.557)	(−0.112)	
	(−0.591)	(0.011)	(−0.009)	(−0.010)		(−0.060)	(−0.422)	(−0.356)	(−0.079)	
$I(0)$ 10% cv	±0.854	±0.683	±1.030	±0.908		±1.570	±1.330	±1.140	±0.936	
$I(0)$ 5% cv	±1.120	±0.883	±1.350	±1.200		±2.190	±1.760	±1.500	±1.270	

Notes: ** and * Denote significance at the 5% and 10% level using a one-tailed test. Values in parentheses are the $t - PS_T$ statistics with the first appropriate for a 10% test and the second appropriate for a 5% test. The last two rows report the 10% and 5% asymptotic critical values. The b's used to compute the statistics can be found in Vogelsang (1997). Newfoundland regression results for $T_b = 1946$ are not possible since Newfoundland became a province only in 1949.

Table 4. Empirical results using the y_t regression and $T^{-1/2}t_y$

Province	Known break date: T_b = 1946				Unknown break date				
	μ_1	β_1	μ_2	β_2	μ_1	β_1	μ_2	β_2	T_b
Alberta	−0.059	−0.334	0.019	0.029	0.172	−4.711	−0.043	0.169	1936
	(−0.187)	(−0.132)	(0.093)	(0.043)	(0.486)	(−0.905)	(−0.302)	(0.416)	
British Columbia	0.266**	−0.441	0.192**	−0.367	0.206**	0.576	0.205**	−0.328*	1938
	(2.185)	(−0.455)	(2.482)	(−1.392)	(1.487)	(0.330)	(3.276)	(−1.778)	
Manitoba	−0.012	−0.328	−0.004	−0.233	0.000	−0.501	0.001	−0.240	1945
	(−0.094)	(−0.316)	(−0.045)	(−0.826)	(0.004)	(−0.493)	(0.016)	(−0.961)	
New Brunswick	−0.461**	0.318	−0.448**	0.478*	−0.465**	0.374	−0.457**	0.590**	1951
	(−3.532)	(0.306)	(−5.405)	(1.690)	(−5.191)	(0.644)	(−6.794)	(2.317)	
Newfoundland	xxx	xxx	xxx	xxx	−0.726**	1.218**	−0.403**	1.152*	1979
					(−14.142)	(4.350)	(−5.698)	(1.669)	
Nova Scotia	−0.362**	0.834*	−0.337**	0.349	−0.358**	0.779	−0.342**	0.377*	1947
	(−3.424)	(0.991)	(−5.023)	(1.526)	(−3.880)	(1.110)	(−5.651)	(1.786)	
Ontario	0.197**	0.078	0.194**	−0.269	0.112*	1.838	0.231**	−0.275**	1933
	(1.864)	(0.093)	(2.893)	(−1.176)	(0.771)	(0.637)	(4.852)	(−2.123)	
PEI	−0.616**	−0.062	−0.665**	0.936**	−0.622**	0.018	−0.549**	0.932*	1958
	(−3.126)	(−0.039)	(−5.315)	(2.193)	(−4.258)	(0.024)	(−4.050)	(1.537)	
Quebec	−0.078**	−0.491	−0.162**	0.250	−0.128**	0.321	−0.187**	0.270*	1939
	(−0.781)	(−0.617)	(−2.548)	(1.156)	(−1.220)	(0.261)	(−3.769)	(1.813)	
Saskatchewan	−0.439**	0.713	−0.105	−0.106	−0.078	−5.452	−0.149	0.027	1938
	(−0.683)	(0.139)	(−0.257)	(−0.077)	(−0.119)	(−0.666)	(−0.507)	(0.031)	
$I(0)$ 10% cv	±0.389	±0.676	±1.820	±1.560	±0.671	±1.470	±2.370	±1.480	
$I(0)$ 5% cv	±0.504	±0.887	±2.390	±2.040	±0.875	±2.000	±3.000	±2.010	

Notes: ** and * Denote significance at the 5% and 10% level using a one-tailed test. Values in parentheses are the $T^{-1/2}t_y$ statistics. The last two rows report the 10% and 5% asymptotic critical values. Newfoundland regression results for T_b = 1946 are not possible since Newfoundland became a province only in 1949.

Table 5. Summary of Empirical Results for Relative Per Capita Personal Income

Province	$t - PS_T$: $I(0)$ errors assumed				$t - PS_T$: Robust to $I(1)$ errors				$T^{-1/2}t_y$: Robust to $I(1)$ errors			
	T_b = 1946		T_b Unknown		T_b = 1946		T_b Unknown		T_b = 1946		T_b Unknown	
	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break
Alberta		E		c		E		E		E		E
British Columbia	*C*	C	D	C					C	c	d	C
Manitoba		d		d		d		d				
New Brunswick	*C*	C	C	C	c		c	C	C	C	c	C
Newfoundland	xxx	xxx	C	C	xxx	xxx	C	C	xxx	xxx	C	C
Nova Scotia	*C*	C	C	C	c	c	c	C	C	c	c	C
Ontario	*d*	C		C	d			C	D	c	d	C
PEI	*d*	C	c	C	d	C	c	C	D	C	c	C
Quebec	*D*	C	c	C					D	c	c	C
Saskatchewan	*c*	E	d	d		E		E	C	E		E

Notes: *C* Denotes point estimates consistent with β-convergence that are statistically significant at least at the 10% level.
c Denotes point estimates consistent with β-convergence with only one estimate statistically significant at least at the 10% level.
D Denotes point estimates consistent with divergence that are statistically significant at least at the 10% level.
d Denotes point estimates consistent with divergence with only one estimate statistically significant at least at the 10% level.
E Denotes point estimates very small in magnitude ($<|0.200|$) and statistically insignificant which suggests that β-convergence has occurred (equilibrium growth).
No symbol signifies point estimates that are statistically insignificant and larger in magnitude ($>|0.200|$), making inference about convergence or divergence difficult.

To summarize, the results indicate three main points. First, there is weak support for β-convergence across Canadian provinces during the early 1926–1946 period. This result is broadly consistent with the observations of Williamson (1965), McInnis (1968), Mansell and Copithorne (1986) among others, that there was neither convergence nor divergence in per capita income during the first half of the twentieth century. Second, most of the convergence detected appears to have occurred during the 1946–1996 period. In particular, there is strong evidence in support of β-convergence for the provinces of British Columbia, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island and Quebec. Alberta and Saskatchewan appear to have attained the equilibrium level in 1946 while Manitoba, the apparent lone holdout, seems to have diverged during the same period.[6] Third, the results are quite robust across the various model specifications. Whether incorporating a known or unknown trend break, using or not using the J_T adjustment, or utilizing the y_t or z_t regressions, the point estimates and test statistics tell similar stories. As mentioned previously, power is lower with the J_T adjustment; hence the evidence is weakened. Thus, the conclusions which one derives from these results depend on how conservative one wants to be regarding the presence of unit roots.[7]

4.2. An alternate measure of income

As stated in Sect. 2, per capita earned income is another possible measure of income to use when studying convergence. This measure is attractive since it eliminates the direct effects of inter-provincial government transfers on per capita incomes, and thus helps to show how each province is faring without the benefit of public redistributive programs. Recall that Fig. 2 shows a considerable difference in the paths of earned income and personal income between 1926 and 1990. In particular, earned income displays a slower reduction in regional dispersion than personal income, suggesting that government policies have had a greater effect on Canadian personal income convergence than earned income convergence.[8] Table 6 summarizes results

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[6] It is worth noting that the income convergence characteristics of Canadian provinces in pre- and post-1946 periods appear to be quite different from those of the U.S. regions. For instance, Carlino and Mills (1996) find evidence of U.S. regional convergence from 1929 up until around 1946. After 1946, they find a remarkable slowdown in the rate of convergence for all regions except the Far West, potential evidence that the bulk of convergence occurred pre-World War II and that equilibrium since then has been largely attained in the U.S. (with the exception of the Southeast).

[7] When the y_t and z_t regressions were estimated without a structural break, weaker evidence of β-convergence was found than with one included. Results are available upon request.

[8] This hypothesis is strengthened upon the incorporation of disposable personal income in the analysis. Replicating our tests from the previous section, we find that disposable personal income, which unlike personal income excludes direct (income) taxes, exhibits even stronger convergence tendencies than personal income, with Manitoba converging in disposable personal income as well. Results are available upon request.

Table 6. Summary of empirical results for relative per capita earned income

Province	$t-PS_T$: $I(0)$ errors assumed				$t-PS_T$: Robust to $I(1)$ errors				$T^{-1/2}t_y$: Robust to $I(1)$ errors			
	$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown	
	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break
Alberta	*E*	E		E	E	E		E	E	E		E
British Columbia	*c*	C	d	C	c				C	c	d	C
Manitoba		d		d		d		d				
New Brunswick	*c*	C	c	C			c	C	C	c	c	c
Newfoundland	*xxx*	xxx	d	C	xxx	xxx	d	C	xxx	xxx	d	C
Nova Scotia	*C*	C	C	C	c		c		C	c	c	c
Ontario	*c*	C		C					C	c		c
PEI	*d*	C	D	C	d	C	D	C	D	c	d	C
Quebec	*D*	C	c	C				E	D	c		C
Saskatchewan	*C*	E	c	d		E		E	C	E		E

Notes: *C* Denotes point estimates consistent with β-convergence that are statistically significant at least at the 10% level.
c Denotes point estimates consistent with β-convergence with only one estimate statistically significant at least at the 10% level.
D Denotes point estimates consistent with divergence that are statistically significant at least at the 10% level.
d Denotes point estimates consistent with divergence with only one estimate statistically significant at least at the 10% level.
E Denotes point estimates very small in magnitude ($< |0.200|$) and statistically insignificant which suggests that β-convergence has occurred (equilibrium growth).
No symbol signifies point estimates that are statistically insignificant and larger in magnitude ($> |0.200|$), making inference about convergence or divergence difficult.

obtained by replicating for earned income the methodology used for personal income in the previous section.[9] The post-break results are largely unchanged from those found for personal income, indicating that earned income convergence is occurring as well in the post-war period. However, β convergence tests on individual provinces do not allow us to comment on the speed of convergence of each series.

One alternative is to construct a new dispersion measure using the two series. By subtracting the standard deviation of relative per capita earned income from the standard deviation of relative per capita personal income, it is now possible to test whether earned income is displaying a slower rate of σ–convergence than personal income. Figure 3 displays this series across the time period. Clearly there exists an upward trend. Using the trend break hypothesis tests from the previous sections, we find that (a) the series is stationary, and (b) the time trend is statistically significant at the 5% level.[10] In other words, Canadian personal income, which includes government transfer payments, is converging faster than Canadian earned income, as a whole. This result implies that the federal government is taxing the richer provinces, such as Ontario and British Columbia, and transferring the funds to poorer provinces such as the Maritimes, thus directly affecting personal income convergence. However, it also implies that relative earning power is increasing over time in poorer provinces, perhaps in part due to the redistributive policies. Thus public policies are not causing earned income to stagnate in the poorer provinces, though we cannot say whether earned income convergence would have occurred at a slower or faster rate without federal intervention. [11]

4.3. Convergence clubs

The results presented in the previous sections have indicated that no matter what measure of income one uses, some tendency towards convergence existed in most provinces in 1946–1996, but not in 1926–1946. In this section, we consider the possibility of the existence of convergence clubs, as first noted by Baumol (1986), by studying the income convergence properties of neighboring provinces with fairly similar economic characteristics, notably the Atlantic and Plains provinces. For example, economic activities in the Atlantic provinces primarily evolved around fishing and fish-related processing while those in the Plains are largely agriculture and resource based. Clearly, provinces with similar geographical and structural (including resource endowment) features in close proximity to one another ought to display at least as strong convergence as Canada as a whole.

[9] Unit root tests show that stochastic convergence holds for all provinces using log of relative per capita earnings. Results are available upon request.

[10] No structural break was included in the regression initially; thus the estimated equation was simply $y_t = \mu + \beta t + u_t$. Results remained unchanged using the z_t regression as well. Incorporating a structural break did not qualitatively change the results.

[11] We were recently made aware of the parallel work on Canadian provincial income convergence by Rodriguez (2003). Using a slightly different sample period and different definition of relative per capita incomes, his findings are broadly consistent with ours.

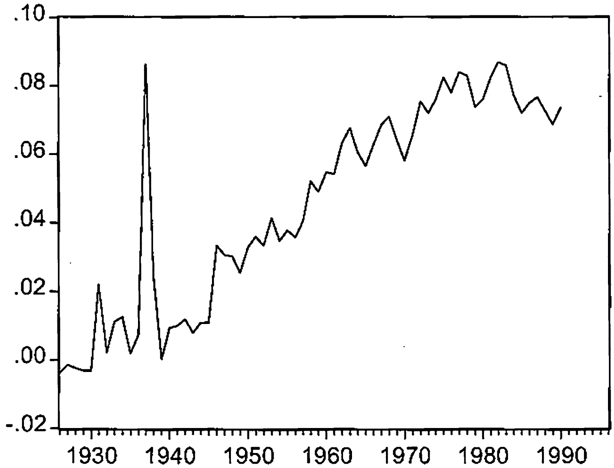

Fig. 3. Dispersion (earnings) minus dispersion (personal income).

4.3.1. Atlantic convergence club

We first investigate whether the log of relative (to the Atlantic provinces as a whole) per capita incomes exhibits stochastic convergence. The results of ADF tests are reported in Table 7a. Over the entire sample period, the null hypothesis of a unit root cannot be rejected at conventional significance levels for New Brunswick and Newfoundland, but can be rejected for Nova Scotia and Prince Edward Island. During the postwar period, however, the unit root null can be rejected for New Brunswick, but not for Newfoundland. The nonrejection of the unit root null for Newfoundland can be due simply to the low stationarity detection power of the ADF test in near unit root cases. We also use a test developed by Kwiatowski et al. (1992) that maintains stationarity as its null hypothesis. As it turns out, there is evidence to suggest that stochastic convergence holds for Newfoundland as well, based on this alternative test.

Turning our attention to β-convergence, Table 8a summarizes the regression results of trend functions tests in both the known and unknown

Table 7a. Unit root tests for the atlantic provinces data series: Natural logarithm of relative per-capita personal income

Province	1926–1996		1946–1996	
	ADF t-statistic	ADF lags	ADF t-statistic	ADF lags
New Brunswick	−2.333	1	−4.065**	1
Newfoundland	−2.282	0	−2.282	0
Nova Scotia	−3.165*	0	−3.133*	0
PEI	−4.945**	0	−5.388**	0

Notes: ADF is the Augmented Dickey and Fuller test with a data dependent lag length chosen according to the Schwarz information criterion. Critical values for the test are obtained using the response surface method advocated by MacKinnon (1991) −3.166 (10%), −3.476 (5%), and −4.096 (1%). ** and * denote significance at the 5% and 10% level.

Table 7b. Unit root tests for the plains provinces data series: Natural logarithm of relative per-capita personal income

Province	1926–1996		1946–1996	
	ADF t statistic	ADF lags	ADF t-statistic	ADF lags
Manitoba	−4.347**	0	−4.581**	0
Saskatchewan	−4.549**	0	−4.576**	0

Notes: ADF is the Augmented Dickey and Fuller test with a data dependent lag length chosen according to the Schwarz information criterion. Critical values for the test are obtained using the response surface method advocated by MacKinnon (1991) −3.166 (10%), −3.476 (5%), and −4.096 (1%). ** and * denote significance at the 5% and 10% level

break date model. The results indicate that divergence seems to be the norm during the pre-break period. However, in the post-break period, there is strong evidence of β-convergence, except for New Brunswick which seems to have attained a level of per capita income, and income growth rate, similar to that of the rest of Atlantic Canada at the end of World War II. Thus our hypothesis that convergence in the Atlantic provinces has been occurring at a faster rate than Canada as a whole appears to hold.[12]

4.3.2. Plains convergence club

Tables 7b and 8b report the test results for stochastic convergence and β convergence for the two Plains provinces, Manitoba and Saskatchewan. The unit root null hypothesis can be rejected for both Manitoba and Saskatchewan, implying that the provinces are stochastically converging to the Plains' average per capita income level. In contrast to the Atlantic provinces, there is evidence that β convergence took place in Manitoba and Saskatchewan during the pre-break period, and by the end of World War II, these two provinces had achieved regional equilibrium. Thus, the bulk of convergence occurred before World War II among the Plains provinces.

5. Concluding remarks

Canadian provinces definitely seem to have been making long strides towards true income convergence since the end of World War II, with the exception of Manitoba. Though equilibrium for all provinces has not been achieved, the trend of shrinking disparities has shown little sign of reversing or halting in recent years. Using new econometric techniques, this paper has demonstrated that σ–convergence, stochastic convergence and β–convergence in personal income occurred for most provinces in the postwar period. Moreover, these results are quite robust to alternate model specifications and assumptions

[12] As an alternative to examining convergence clubs, one could test and adjust for the presence of spatial correlation across adjacent provinces as a way of learning to what extent spillovers affect regional convergence. Recent studies that have used this methodology include Rey and Montouri (1999) for the United States. We leave this worthwhile endeavor to a future paper.

Table 8a. Summary of empirical results for relative per capita personal income in maritime provinces

Province	$t-PS_T$: $I(0)$ errors assumed				$t-PS_T$: Robust to $I(1)$ errors				$T^{-1/2}t_y$: Robust to $I(1)$ errors			
	$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown	
	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break
New Brunswick	*D*	C	D	C	d	E	d	E		E		E
Newfoundland	xxx	xxx	C	C	xxx	xxx	c		xxx	xxx	c	C
Nova Scotia	*D*	C	D	C	E	E	d	c	d	c	d	c
PEI	*D*	C	D	C	D	C	d	C	d		d	

Notes: See notes in Table 8b

Table 8b. Summary of empirical results for relative per capita personal income in plains provinces

Province	$t-PS_T$: $I(0)$ errors assumed				$t-PS_T$: Robust to $I(1)$ errors				$T^{-1/2}t_y$: Robust to $I(1)$ errors			
	$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown		$T_b = 1946$		T_b Unknown	
	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break	Pre-break	Post-break
Manitoba	*C*	E	d	c	c	E		E	c	E		E
Saskatchewan	*C*	E	c	C	c	E		C	c	E		E

Notes: *C* Denotes point estimates consistent with β convergence that are statistically significant at least at the 10% level.
c Denotes point estimates consistent with β -convergence with only one estimate statistically significant at least at the 10% level.
D Denotes point estimates consistent with divergence that are statistically significant at least at the 10% level.
d Denotes point estimates consistent with divergence with only one estimate statistically significant at least at the 10% level.
E Denotes point estimates very small in magnitude ($< |0.200|$) and statistically insignificant which suggests that β -convergence has occurred (equilibrium growth).
No symbol signifies point estimates that are statistically insignificant and larger in magnitude ($> |0.200|$), making inference about convergence or divergence difficult

regarding both unit roots and the choice of break date. Convergence has occurred for earned income as well, though at not as fast a rate, highlighting the fact that federal transfer programs play a part in redistributing wealth from richer to poorer provinces and hence foster faster personal income convergence. Finally, convergence clubs, notably the Atlantic provinces and Plains provinces, are found to display stronger convergence properties than Canada as a whole, a result that supports Baumol's (1986) theory of convergence clubs.

Overall, our findings support Solow's (1956) neoclassical growth model. Also, despite differences in econometric methodology and time coverage, our findings are consistent with and complement previous research such as Williamson (1965), Chernick (1966), and McInnis (1968) that offer little support for convergence in the years before World War II, and Coulombe and Lee (1995), Helliwell (1996) and Coulombe and Day (1999) that provide support for convergence across Canadian provinces in the years after World War II.

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