CJRS (Online)/ RCSR (en ligne) ISSN : 1925-2218
Vol. 33 (2): 175-190

CONVERGENCE MEASURES BETWEEN AND WITHIN CANADA AND CHINA

Ablajan Sulaiman
Laboratoire de Développement durable et dynamique territoriale
Géographie
Université de Montréal
C.P. ?128, Succursale Centre-ville
Montréal, Québec
Canada H3C 3J7
ablajan.s@gmail.com

Christopher Bryant
Laboratoire de Développement durable et dynamique territoriale
Géographie
Université de Montréal
C.P. ?128, Succursale Centre-ville
Montréal, Québec
Canada H3C 3J7
chris.r.bryant@umontreal.ca

Abstract.
This study attempts to compare and measure cross-country convergence between and within Canada and China at the national scale by using recently released long term data and to derive new evidence of convergence in each country using different measurement methods for the period 1961-2007. Under this precondition of existence of absolute β-convergence, σ-convergence and cross-country beta convergence (including conditional convergence) were tested. The estimated coefficient of Conditional β-convergence was weighted by the population factor. Finally, the spatial analysis including the spatial error model (SEM), the spatial lag model (SLM), and the spatial cross-regressive models (SCM) were also taken into consideration in the beta convergence analysis of each country individually.

Key Words: σ-convergence and β-convergence, Spatial Analysis, Canada, China.

JEL Codes: O11, O18, O47, R12.

Résumé. Des indicateurs de convergence entre et au sein du Canada et la Chine.
Que les économies pauvres ont tendance à converger vers les pays riches, ou bien à diverger au fil du temps est une question qui a attiré l'attention des décideurs et des universitaires depuis quelques décennies. Convergence ou divergence économique est un sujet d'intérêt et de débat, non seulement pour valider ou non les deux modèles principaux de croissance qui sont considérés comme concurrent (l'approche néo-classique et celle des approches de croissance endogène), mais aussi pour ses implications pour les publiques politiques.

Que les économies pauvres ont tendance à converger vers les pays riches ou bien à diverger au fil du temps est une question qui a attiré l'attention des décideurs et des universitaires depuis quelques décennies. Les deux économies du Canada et de la Chine se sont développées depuis la Seconde Guerre mondiale, mais la Chine a connu une croissance plus rapide que le Canada comme en témoignent de nombreux indicateurs depuis 1980. La convergence des deux pays à l'échelle nationale et la convergence provinciale pour chaque pays sont examinés en utilisant différentes méthodes de mesure telles que les méthodes traditionnelles, la convergence bêta et la convergence sigma. Enfin, L'analyse spatiale est également prise en considération dans l'analyse de convergence pour chaque pays pris séparément. Les résultats empiriques et les processus de convergence et de divergence offrent un cadre intéressant pour l'examen de la trajectoire de développement régionale et les disparités régionales dans les deux économies. Les résultats de cette étude démontrent que la disparité en termes de revenu régional est une réalité dans chaque pays.

Les résultats empiriques de convergence démontrent que le développement économique régional en Chine est plus déséquilibré qu'au Canada. Il y a des écarts importants entre les deux pays dans de nombreux indicateurs. Tous les résultats des analyses ont démontré qu'au Canada la disparité entre les provinces a diminué progressivement depuis 1960, tandis qu'en Chine, la disparité entre les provinces a diminué au cours de la période de 1981 à 1990, puis a augmenté jusqu'en 2003, après quoi il a diminué ou est demeuré au même niveau. Si les deux pays sont comparées, pour toute la période étudiée il y avait divergence entre les deux économies. On peut en conclure que les disparités provinciales en Chine sont plus grandes qu'au Canada. L'analyse a révélé que la plupart des indicateurs pour la Chine ont augmenté plus rapidement que pour le Canada pendant toute la période à l'étude.

Mots clé : σ-convergence, β-convergence, analyse spatiale, le Canada, la Chine.

Codes JEL : O11, O18, O47, R12.

Introduction

Whether poor economies tend to converge towards rich ones or else to diverge over time is an issue that has been explored by a considerable amount of empirical convergence-divergence research since the early 1990s. One of the important findings of the neoclassical growth model is its prediction of convergence — poor nations or regions tend to grow faster than rich ones in terms of the level of per capita product or income (Barro and Sala-i-Martin, 1991). However, these studies are mostly focused on comparisons between developed countries, or between developing and undeveloped countries. There are many empirical and theoretical studies on Canadian and China's regional disparities and regional convergence mainly based on the single indicator of Gross Domestic Product (GDP) as well as some other indicators.

In the case of Canada, one of the first to quantify this situation was McInnis (1968) who concluded that "the trend of regional income differentials in Canada appears to have been roughly a constant for the period 1926-1962; there has been neither convergence nor divergence" (McInnis, 1968: 441). At the provincial level, the dispersion indices of various income and output measures record a substantial convergence among Canadian provinces from the 1950s to the mid-1980s. Since the mid-1980s, the catch-up convergence process appears to have come to an end. The dispersion indices converge slowly suggesting that the system is approaching a steady state (Coulombe, 1999). Lefebvre (1994) examined whether the hypothesis of economic convergence holds for Canadian provinces by using data on real gross domestic product per capita and on factor productivity from 1966 to 1992. His results support the findings of other authors who have studied convergence among Canadian provinces. Afxentiou and Serletis (1998) found some results that conflicted with the work of Coulombe and Lee (1993), and concluded that the various regional developmental policies and transfers introduced after 1960 had neither sped up nor slowed down the overall convergence process. Ralhan and Dayanandan (2005) measured unconditional and conditional income convergence among provinces in Canada during the period 1981-2001 they found higher convergence rates of around 6% to 6.5% p.a. whereas the previous studies using OLS (Ordinary Least Squares) and other techniques reported a convergence rate of around 1.05% for per capita GDP and 2.89% for personal disposable income among Canadian provinces. James and Krieckhaus (2008) emphasized the importance of initial income in explaining growth variation across individual units and they found that Canadian provinces do show convergence over time in terms of overall economic performance.

In the case of China**,** a great deal of research has been undertaken to measure regional income convergence and income inequality from different factors. For example, Weeks and Yao (2003) based on the Solow growth model found conditional convergence in both the pre-reform (1953-1978) and reform (1978-97) periods with the convergence speed in the reform era being much faster than during the pre-reform period. Jian et al (1996), on the other hand, found that China's real income convergence developed strongly since the 1978 reform, a period strongly associated with the adoption of the market economy approach and openness to external trade. However, they noted a divergence in regional income between the coastal and non-coastal regions since 1990. Zhang et al (2001) and Wang and Ge (2004) suggested that China's regions, especially the eastern and western regions, have converged to their own specific steady states over the past 40 years, while the differences between the east and west regions have widened. Yao and Zhang (2001) proposed a production model to explain regional divergence based on the hypothesis that in developing countries where technology and capital are scare, initial economic growth depends on the economic spill-over from growth centres. In contrast to some previous studies, they found that regions in China did not converge in the reform period. While previous literature recognises the importance of space and geography in China's growth process, Aroca et al (2008) using the non-parametric methods of kernel density function and Markov chain analysis analysed regional convergence from spatial interactions.

However, there are few studies on the comparisons between Canada and China due to the difficulty of comparisons such as differences in income level and status, population size, statistical collection system, government system and its composition, and public policy. While the previous literature recognises the importance of measuring convergence in Canada and China independently, there are few studies in convergence analysis which has been tailored specifically to take some additional indicators and other related spatial effects into account in cross-country convergence analysis. Exploring this issue would constitute a significant advance in the cross-country analysis of two countries with different income levels and status. In this study, we expect to fill this gap and to report new information derived from the application of new methods in the analysis of regional income convergence between Canada and China.

Methodology

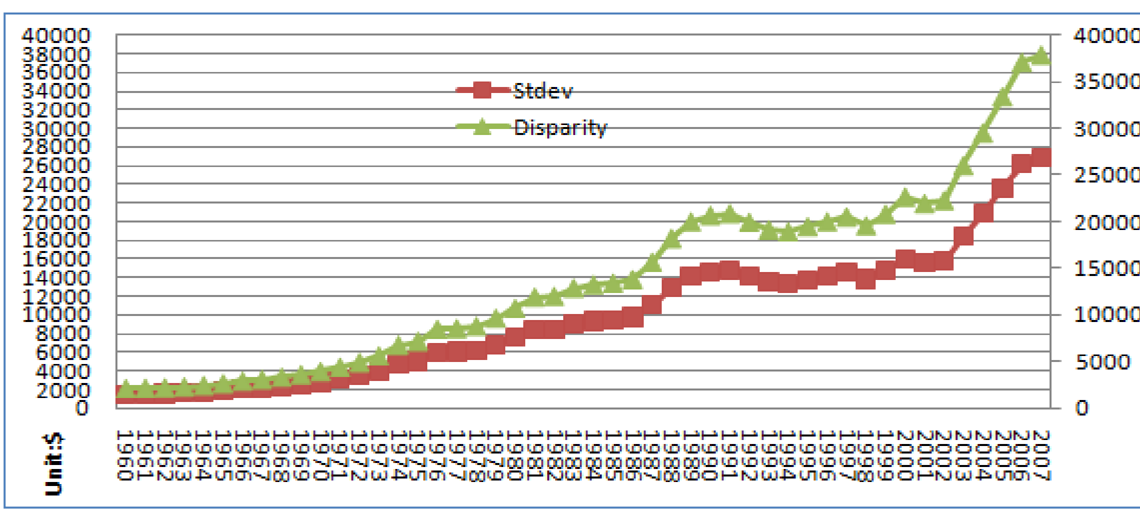
One of the difficulties in this study is that of securing adequate and reliable statistical data from 1949 to 1978 from China's statistical data sources. Statistical data are publicly available since 1980 in China. The other difficulty is the comparability of indicators between the two countries. Furthermore, the question arises concerning the conformity of these statistical indicators with Canada's statistical indicators. Because of this, the analysis of the statistical data is mainly focused on the time period between 1980 and 2008.

In this study, to start with a simple descriptive per capita GDP is analysed to see if there are signs of convergence between two countries. The length of the convergence process is assessed by using different indicators. Then, the existence of both β-convergence (which refers to the narrowing of income disparities) and σ-convergence (which tells whether poor economies are growing faster than rich ones) are tested. Finally, spatial analysis is taken into consideration in the convergence analysis. The details follow.

Empirical Analysis

To explain whether China has succeeded in achieving convergence with Canada in relation to GDP per capita as well as on the other indicators, we must compare China's and Canada's progress in a comprehensive way using multiple indicators to provide as robust an explanation as possible. If calculated on a per capita basis, China ranked in a worse position with a ranking of 105 based on GDP per capita PPP (Purchasing Power Parity) ($6,546 in 2009), while Canada ranked in 12th position ($38,290) in GDP per capita (PPP)[1]. China's annual average growth rate was much faster between 1960 and 2007 and even went into the double digits in some sub-periods during the period 1980-2007. If we compare recent trends, China achieved an 11.94% and Canada a 4.39% GDP (PPP) annual growth per capita in the period 1981-2009[2]. If we analyse a long series of data for GDP per capita, the annual growth rate of China was 8% during the period 1961-2008 while for Canada it was a 3.6% annual growth rate during the same period. The rate of growth of China is faster than Canada, so there is absolute Beta-convergence between the two countries. However, China is listed far from the high level countries in ranking, but above the average world level if calculated by the GDP index, per capita GDP, HDI (Human Development Index), Life Expectancy Index and Education Index, among the 208 countries and territories in the world.

FIGURE 1 Standard deviation and disparity of per capita GDP between Canada and China



Source: Based on the GDP (current US$) and population data report of World Bank 2009.

[1] http://www.imf.org/external/data.htm
[2] http://www.indexmundi.com/

It can be seen that both economies increased gradually while the disparity of per capita GDP between both countries has become greater. It is not possible for the income gap between Canada and China to narrow if the initially 'poor' country, in this case China, does not grow faster than the initially 'rich' one, or Canada. The disparity in per capita GDP between both countries increases from $2,108 in 1960 to $41,826 in 2008 and the standard deviation of Per Capita GDP increases from $1,490.5 to $29,575 during the period 1960-2008. If we consider the standard deviation and disparity per Capita PPP of both countries from 1981 to 2007, the per capita PPP of both countries increased since 1981, and then decreased from 2007. But the disparity has diverged since 1981 gradually (Figure 1**)**.

The Assessment of the Time Required for Convergence

The most frequent question concerning economic growth convergence refers to the length of the process. Specifically, when we analyse the convergence of the real economies of China and Canada, the first thing to be clarified is the length of the period necessary to achieve the future balance between China's annual average income per capita (Y_{CN}) and Canada's one (Y_{CA}). The initial level of GDP per capita (PPP in US$) of the two entities ($Y_{CN}$ and Y_{CA}) is characterised by a significant difference. The ratio of Y_{CA} to Y_{CN} was 1: 26.4 in 1961, and 1: 15.7 in 2007. The balance may occur in a reasonable period of time, only if China is able to achieve annual average growth rates per capita (r_{CN}) much higher than those achieved by Canada (r_{CA}).

To assess the convergence period we start with the simple relationships concerning the GDP per capita growth of the two entities with different initial levels and annual average growth rates:

$$Yt_{CN}= Y_{CN}\,(1+ \check{r}_{CN})^{t} \qquad (1)$$

$$Yt_{CA}= Y_{CA}\,(1+ \check{r}_{CA})^{t} \qquad (2)$$

Convergence is achieved when the values of the two relations become equal according to the relation: $Y_{CN}\,(1+ \check{r}_{CN})^{t}= Y_{CA}\,(1+ \check{r}_{CA})^{t}$ (3)

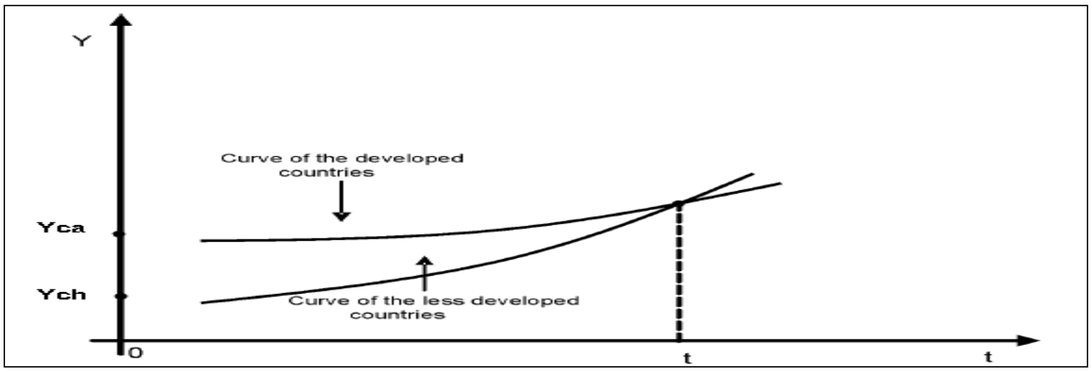
and the curves Yt_{CN} and Yt_{CA} meet in the balance point t^* according to Figure 2.

By logging and rearranging the terms, one may assess the period of time (t) when the convergence (balance) of the GDP per capita of the two entities is achieved:

$$T=\log Y_{CA}- \log Y_{CN}/ \log(1+ \check{r}_{CN})- \log(1+ \check{r}_{CA}) \qquad (4)$$

Using this formula 4, we may calculate the period of time (in years) when China can catch up (in terms of the GDP per capita calculated by the PPP in US$) with Canada. Table 1 includes the data used in the calculation formula (initial GDP per capita and the annual average growth rates) and the results representing the number of years required to achieve convergence with Canada, in relation to China's annual growth rates, considered as alternatives (r_{CN1}=4%, r_{CN2}=5%, r_{CN3}=6%, r_{CN4}=7%, r_{CN5}=8%, r_{CN6}=9%) in relation to Canada's annual growth rates considered as alternatives r_{CA1}=1%, r_{CA2}=2%, r_{CA3}=3%, r_{CA4}=4%).

FIGURE 2 The Convergence of the Economic Growth Curves of Developed and Less Developed Countries



Source: Modified from *Dynamics in the Neo-classical Model* (Barro and Sa1a-i-Martin, 1995).

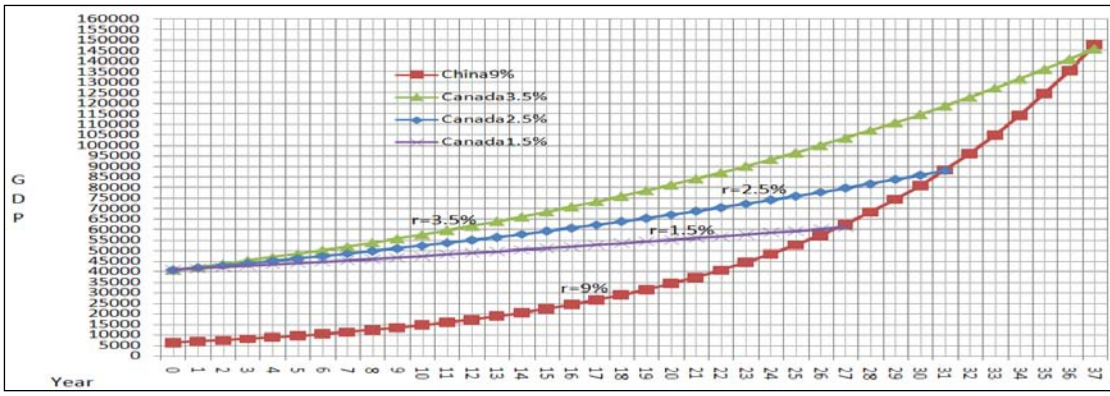
TABLE 1 Forecasting the time to Achieve Convergence between China and Canada

Indicators	Canada Y_{CA}	China Y_{CH}	Annual average growth rate of Canada	The time to achieve the convergence of alternative annual growth rates of China (r_{CN1},.. r_{CN6})					
				r_{CN1}=4%	r_{CN2}=5 %	r_{CN3}=6%	r_{CN4}=7 %	r_{CN5}=8 %	r_{CN6}=9%
GDP(PPP)/2008	40900$	6100$	$\check{r}_{CA}$ =3.5%	395	132	80	57	45	37
	40900$	6100$	$\check{r}_{CA}$ =2.5%	131	79	57	44	36	31
	40900$	6100$	$\check{r}_{CA}$ =1.5%	78	56	44	36	31	27
HDI/2008	0.961	0.777	$\check{r}_{CA}$ =0.275	$\check{r}_{CN}$ =0.772	43				
Urban Pop 2008	80.1%	44.9%	$\check{r}_{CA}$ =0.143	$\check{r}_{CN}$ =0.89	78				
Gini index	32.6	46.9	$\check{r}_{CA}$ =0.16	$\check{r}_{CN}$ =0.66	73				
LEI 2006	0.924	0.795	$\check{r}_{CA}$ =0.21	$\check{r}_{CN}$ =0.006	151				
GDP I2008	0.986	0.642	$\check{r}_{CA}$ =0.0045	$\check{r}_{CN}$ =0.009	96				
OPENC2004	73.4	54.38	$\check{r}_{CA}$ =0.5	$\check{r}_{CN}$=1.5	30				

Note: The Annual average growth rate of indicators ř are calculated with the data of GDP(1961-2008), HDI (1975-2008), UrbanPop, Gini index (1998-2008), Life expectancy index(LEI) (1995-2006), GDPI-GDP Index (2000-2008), OPENC-Openness(1950-2004), Engel Coefficient (Canada 1968-2008) China 1978-2008) from difference sources such as PWT6.2 Database, World Bank Database; IMF Database; UN Database; FAO Database; UNCTAD World Investment Report 2007; UNDP Human Development Reports of different years. Average urbanisation rate is calculated based on 1980-2008 data of both countries.

If China maintains a high growth rate as shown in the data in Table 1, the convergence time can theoretically be estimated. At an annual average growth rate of 6%, China would need 80 years to reach Canada's level. At a growth rate of 7%, the number of years to achieve convergence with Canada would diminish to less than half, i.e. 45 years, and at a rate of 9%, convergence with Canada requires 37 years. The dynamics of the GDP per capita points of convergence of China and Canada in relation to China's average growth rates compared to Canada's rate is shown in Figure 3, where the abscissa contains the time (number of years) necessary to achieve the convergence, and the ordinate indicates the evolution of the GDP per capita in China, as given by the 9% annual average rate of China and the 3.5% annual average rate of Canada (Table 1).

FIGURE 3 The Dynamics of Convergence between China and Canada in Relation to GDP Per Capita by Size of Annual Average Growth Rate in China



Source: Calculated based on World Bank Data.

At a 9% growth rate for China's economy and one of 3.5% for Canada, the convergence point (curve intersection) of the two entities will be achieved at a GDP per capita of about 147,000 $, i.e. in 37 years, while with a rate of 9% for China and 1.5% for Canada, the convergence of the two entities will be achieved at a GDP per capita of about 62,000 $, i.e. 27 years (Figure 3). These figures seem impossible and unbelievable to achieve in near future. But fast economic growth even during the recent world economic recession became a distinguishing feature of the Chinese 'economic miracle'. It is precisely by extrapolating the current trends into the future that many experiments have conjured up a picture of that formerly backward country as becoming an economic superpower that could catch up with the industrialised countries.

σ-convergence and β-convergence

σ-*Convergence:* A frequently used indicator for the convergence measurement is the coefficient of variation of the GDP per capita denoted by σ and calculated as follows:

$$\sigma = \sqrt{(1/n)\sum (x_i - \bar{x})^2} \Big/ \bar{x} \qquad (5)$$

where x_i is the value of the variable of interest for the *i*th region, there are *n* regions, and $\bar{x}$ is the sample mean for x. A higher value of σ- convergence indicates a more serious income disparity, and *vice versa*.

To compare Canada and China, the population factor should also be taken into consideration. So σ can be transformed into a new weighted one, σ_w, by simply employing a population weighted variance $\frac{Pop_i}{Pop^*}$ given by the expression below:

$$\sigma_w = \frac{\sqrt{\sum_{i=1}^{N} \frac{Pop_i}{Pop^*} \left(x_i - \bar{x}\right)^2}}{\bar{x}} \tag{6}$$

where x_i, is the value of the variable of interest for the *i*th region, there are n regions, $\bar{x}$ is the sample mean for x , p_i is population of the *i*th region, and pop^* is the national population.

Barro and Sala-i-Martin (1995: 383) pointed out that the dispersion can be measured by calculating the standard deviation of the per-capita logarithm for each year. The following formula will be used to estimate the standard deviation for each year:

$$\sigma_t = \sqrt{(1/n).\sum_{t=1}^{n} \left(\ln \bar{x}_t - \ln x_{it}\right)^2} \tag{7}$$

where σt stands for the standard deviation at period t, $\ln \bar{x}$ and $\ln x_{it}$ represent the logarithm of the average per capita GDP of regions at period t and the logarithm of per capita GDP in region i at period t respectively; and n is the number of regions. If σ_{t-1} is less than σ_t, then σ-convergence exists. However, if σ_{t-1} is more than σ_t, then σ convergence does not exist.

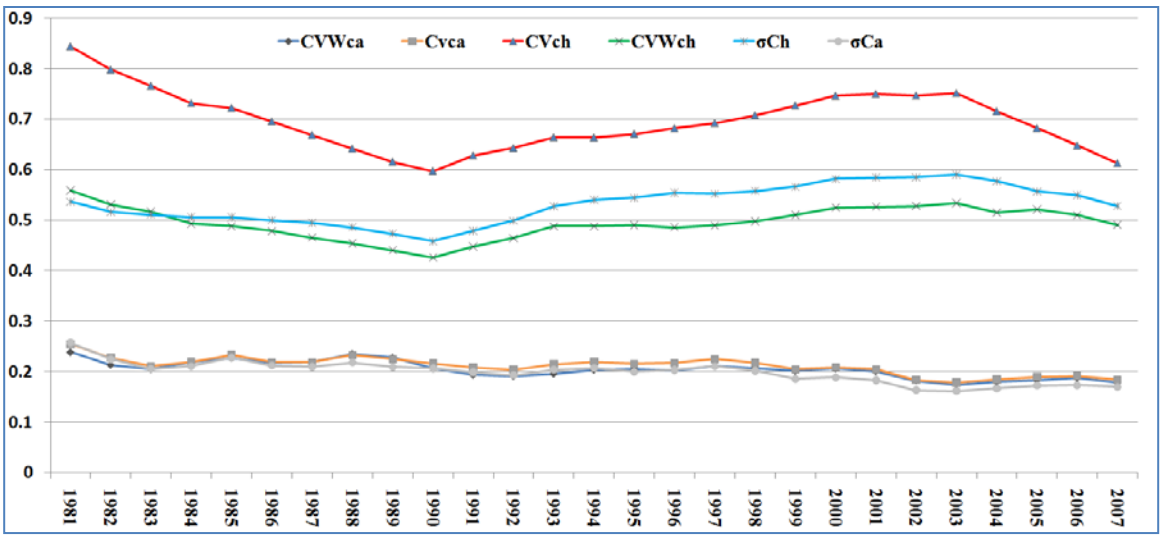
It can be seen from Figure 4 that from 1981 to 2007, Canada experienced a significant provincial σ convergence for the whole period while China experienced provincial σ convergence from 1981 to 1990 and σ divergence from 1991 to 2003, with convergence starting again from 2004. If we compare the cross-country analysis, the distance of the curved σ convergence lines between both countries seems to have converged slightly for the period 1981-1990, and then diverged gradually. If we compare the weighted σ convergence that takes into account the population factor, there is significant divergence between both countries.

β Convergence: To test if an initially lower income country has a higher rate of income growth, researchers often use two types of equation to estimate β convergence: absolute convergence and conditional convergence. Beta convergence is defined as a negative relationship between initial income levels and subsequent growth rates. Beta convergence analysis has generally been employed in order to investigate convergence across economies or regions using cross-sectional data, and involves implementing the following model:

$$\ln(y_{i0+T}/y_{io})/T=\alpha_0+ \beta_1 \ln(y_{io})+\varepsilon_i \tag{8}$$

where y_{i0} – initial GDP per capita in region *I*, T – number of years in observation period, α_0, β – parameters to be estimated, ε_i- normally and independently distributed error term. In particular, if we consider estimations based on equation (8) these are referred to as absolute β convergence. The annual rate of convergence can be obtained from the equation β =-ln (1- β_1)/T, where T denotes the number of years between the initial year and the final year of observation. If $\beta<0$ and is statistically significant, it is inferred that there is β-convergence, If, on the contrary, $\beta >0$, then it is said there is β-divergence. A significant negative estimate can be interpreted as evidence of absolute convergence. The convergence rate measures how fast economies converge towards the steady state. The half-life Γ= ln (2)/ β is defined as the time which is necessary for half of the initial income inequalities to vanish. Model (8) is estimated by a non-linear version of the basic growth regression, for different periods (Table 2).

FIGURE 4 Weighted (CVW) and Unweighted σ-convergence (CV) and Standard Deviation (σ) of Canada and China 1981-2007



Note: China includes 31 provinces and cities. Canada includes 10 provinces; the 3 territories are excluded in the calculation because of data availability problems.

The regression results do not confirm the convergence hypothesis in all cases with the “beta” coefficient being negative. For the whole period (61-07), the countries converge at a speed of 0.32% per year, but it is not very significant. In the first sub period 1961-1980, the rate of divergence is 1.17% per year while in the second sub-period, 1981-2007, the convergence rate is 1.02%. Generally, the estimation results are not satisfactory and no serial correlation has been found in all cases. For the short periods 1961-1970, 1971-1980 and 1981-1990, there was divergence at different rates 0.63%, 1.29% and 0.18% respectively, but during the other short periods both countries converge at a rate of 2% in the period of 1991-2000 while they converge at the rate of 1.26% in the period 2000-2007. Finally, the results are partially consistent with the “sigma” convergence analysis where we found a fall in the dispersion of per capita income in the last sub-period 2001-2007 and divergence in the period 1981-1990.

Estimation results of β-convergence at national level: Based on Model 8, the provincial beta convergence of each country can be calculated by regressing the average growth rate of per Capita GDP between time t_{beg} = 1981 and time t_{end} = 2007 on initial income at time t_{beg} = 1981 where:

$$(\ln Yit_{(end)} - \ln Y_{it(beg)})/ T = \alpha + \beta \ln Y_{it(beg)} + \mu_i \qquad (9)$$

Here, i is the index for each region where i = 1 to 10 in Canada while i = 1 to 31 in China. Model (9) is estimated by a non-linear version of the basic growth regression, for different periods.

TABLE 2 Cross Country Absolute β Convergence

Year	Country	ln(y0+t/y0)	lny0	Estimation Equation	Annual Rate
61-07	Canada	2.894349886	7.709756864	ln(y0+t/y0) = -0.169453 lny0 + 4.200791	-0.00326
	China	3.467219724	4.329055273		
81-07	Canada	1.203146018	9.400960732	ln(y0+t/y0) = -0.319544 lny0 + 4.207165	-0.01027
	China	2.521710491	5.274564506		
61-80	Canada	1.586761204	7.709756864	ln(y0+t/y0) = 0.210089 lny0 -0.03297	0.011792
	China	0.876514501	4.329055273		
61-70	Canada	0.596715296	7.709756864	ln(y0+t/y0) = 0.061779 lny0 + 0.120416	0.006377
	China	0.387859528	4.329055273		
71-80	Canada	0.884685392	8.411832676	ln(y0+t/y0) = 0.121389 lny0 -0.136419	0.012941
	China	0.441844969	4.763724805		
81-90	Canada	0.551316985	9.400960732	ln(y0+t/y0) = 0.018204 lny0 + 0.380179	0.001837
	China	0.476198901	5.274564506		
91-00	Canada	0.107245529	9.961756461	ln(y0+t/y0) = -0.228183 lny0 + 2.380351	-0.02055
	China	1.057268887	5.798331997		
01-07	Canada	0.56085726	10.04324949	ln(y0+t/y0) = -0.092697 lny0 + 1.491837	-0.01266
	China	0.847727074	6.948547923		

TABLE 3 National β Convergence for Each Country

Country	Year	B	R	(5% significance)
Canada (10 regions)	1981-2007	-0.442724	(r) = -.719245 (r^2 = .517313)	65.24%
	1981-1990	-0.201322	(r) = -.883984 (r^2 = .781428)	95.05%
	1991-2000	-0.076575	(r) = -.28943 (r^2 = .08377)	11.81%
	2001-2007	-0.144079	(r) = -.372104 (r^2 = .138462)	17.28%
China	1981-2007	-0.160544	(r) = -.28066 (r^2 = .07877)	32.49%
	1981-1990	-0.171818	(r) = -.52254 (r^2 = .273048)	85.71%
	1991-2000	0.154364	(r) = .43113 (r^2 = .185873)	67.31%
	2001-2007	-0.116753	(r) = -.44046 (r^2 = .194005)	69.45%

From Table 3, it can be clearly seen that the beta coefficient is negative ($\beta<0$), and is significant in Canada during the whole period and the sub-period 1981-1990. It shows there is strong convergence during the 1981-1990 period and convergence during the whole period while there is weak convergence during the 1991-2000 and 2001-2007 periods.

In the case of China, per capita provincial income converged for the whole period from 1981 to 2007, but it is not very significant. For the sub-periods there is convergence during the period 1981-1990, then divergence during 1991-2000, and convergence again during 2001-2007, and all of these results are very significant. The result can be interpreted as reflecting very closely the regional development policy of China during these periods. The results are consistent with the “sigma” convergence of China where we found a divergence of per capita income dispersion during the first sub period (1981-1990) and a fall in the dispersion of per capita income in the whole period 1981-2007 for China.

In the case of Canada, there is convergence for the whole period (1981-2007) and this is consistent with the sigma convergence of this country. The Absolute Beta Convergence approach assumes that all regions or economies under consideration have the same steady-state income path. But this is a highly restrictive assumption and may induce a significant heterogeneity bias in estimates of the convergence coefficient between different countries with different steady status. In this case, the cross-country absolute convergence of Canada and China does not fully support the absolute convergence hypothesis. So it is necessary to test for conditional convergence.

Conditional β Convergence

Conditional convergence implies that a country or a region is converging towards its own steady state while absolute convergence implies that all countries or regions are converging to a common steady state. To test for conditional β-convergence, equation 10 is extended below by using a set of dummy variables($X_1, X_2, X_3 \ldots X_I$) to control for country-specific effects that differ between individual countries and affect the change in the per capita growth rate. By accounting for these unobserved differences for both countries, it can be determined whether or not country-specific effects influence the test of convergence.

$$1/T \log(Y_{it}/Y_{i0}) = \alpha - 1/T(1-e^{-BT}) \log Y_{i0} + \lambda X_{it} + u_{it} \quad (10)$$

This traditional regression model can be changed into the following form:

$$(\ln Y_{it(end)} - \ln Y_{it(beg)})/ T = \beta_0 + \beta_1 \ln Y_{it(beg)} + \beta_2 X_1 + \beta_3 X_2 + \beta_4 X_3 + \beta_n X_n + \mu_{it} \quad (11)$$

When the estimated coefficient β_1 is negative, poor economies tend to grow faster than rich ones. The annual rate of convergence β_1 can be obtained from the equation $\beta = -\ln(1-\beta_1)/T$, where *T* denotes the number of years between the initial and the final year of observation.

Model (11) is estimated by a multiple (general) linear version of the generalised growth regression, for different periods (Table 4). The regression results do not confirm the convergence hypothesis in all cases with “beta” coefficient being negative. For the whole period, the countries converge at a speed of 0.1045% per year, and 0.2033% per year by the population-weighted regression; the results are not very significant. In the first sub period 1961-1980, the rate of divergence is 0.5429% per year while in the second sub-period, 1981-2007, the convergence is 0.5139%. Generally, the estimation results are not satisfactory (little significance) and no serial correlation was found in any of the cases. For the short periods 1961-1970, 1971-1980 and 1981-1990, there was slower than absolute beta divergence at different rates (0.2233%, 0.3586%, 0.0895% respectively), but during the other short periods both countries converge at a higher speed - 1.09% rate in the period 1991-2000 while they converge at the rate of 1.11% in the period 2000-2007. If the population-weighted conditional Beta Convergence results are compared, there are higher speeds of convergence during the periods 1961-2007 (0.2033%), 1981-2007 (0.8701%), 1991-2000 (1.7%), 2001-2007 (1.11%) while there is a lower speed of divergence during the period 1961-1980 (0.4342%).

Finally, the results are partially consistent with "sigma" convergence where we found a decrease in the dispersion of per capita income in the last sub-period 2001-2007 and divergence in the period 1981-1990.

Spatial Data Analysis

Another dimension of the convergence analysis is that regional economic growth may follow a particular spatial pattern which may indicate the spill-over effects among regions. Convergence patterns can be expected to differ between Canada and China, because of the large territorial size of both countries and the unequal distribution of population and economic centres. Therefore, separate spatial models for both countries are estimated individually. Spatial dependence can be handled in beta convergence in alternative ways.

TABLE 4 Conditional β Convergence

Year	Country	Ln(y0+t/y0)	lny0	x1	x2	x3	x4	x5	x6	Beta	
61-07	Canada	0.06	7.71	21.22	23.75	22.67	22.90	23.23	17.02	β_1	-0.001045
	China	0.07	4.33	23.34	23.64	20.93	23.13	22.23	20.70	β_w	-0.002033
81-07	Canada	0.04	9.40	23.26	25.92	25.12	25.04	25.68	17.03	β_1	-0.005139
	China	0.09	5.27	24.85	24.48	23.92	25.33	24.51	20.72	β_w	-0.008701
61-80	Canada	0.08	7.71	21.39	23.92	22.84	23.07	23.40	17.06	β_1	0.005429
	China	0.05	4.33	23.29	23.59	20.88	23.09	22.19	20.76	β_w	0.004342
61-70	Canada	0.06	7.71	21.60	24.13	23.05	23.28	23.61	17.08	β_1	0.002233
	China	0.04	4.33	23.55	23.85	21.14	23.34	22.44	20.79	β_w	0.003478
71-80	Canada	0.09	8.41	22.18	24.92	23.76	23.81	24.27	16.89	β_1	0.003586
	China	0.05	4.76	24.25	23.88	21.72	24.09	22.31	20.55	β_w	0.005374
81-90	Canada	0.06	9.40	23.88	26.54	25.73	25.65	26.30	17.13	β_1	0.000895
	China	0.05	5.27	25.42	25.05	24.49	25.94	25.08	20.72	β_w	0.001195
91-00	Canada	0.01	9.96	23.52	26.73	25.74	25.44	26.25	17.15	β_1	-0.0109
	China	0.11	5.80	25.26	25.57	25.09	25.64	25.63	20.86	β_w	-0.017639
01-07	Canada	0.08	10.04	25.89	26.88	26.46	25.64	26.91	17.25	β_1	-0.00527
	China	0.12	6.95	25.97	27.01	26.43	26.90	26.96	20.96	β_w	-0.011165

Note: β_1 is the estimated coefficient, β_w the estimated coefficient of regression weighted by the population factor X6. X1 is Agriculture, value added (% of GDP), x2 is Services, etc., value added (% of GDP), x3 is Exports of goods and services (% of GDP), x4 is Gross capital formation (% of GDP), x5 is Merchandise trade (% of GDP), and X6 is population.

Spatial Analysis

Spatial dependence can be handled in beta convergence in alternative ways[3]. The first approach, the spatial error model, assumes that the spatial dependence operates through the error process, where any random shock follows a spatial pattern, so that shocks are

[3] For a detailed analysis of spatial econometric techniques and methods see Anselin (1988, 1995) and Henley (2003).

correlated across adjacent regional economies, such that the error term in equation (13) may reveal a significant degree of spatial covariance, which can be represented as follows:

$$\log(y_{it}/y_{i0}) = a + \delta log y_{i0} + \mu_i \quad (12)$$

$$\mu_i = \rho W \mu_i + \varepsilon_i \quad (13)$$

So substituting (12) into model (13) results in a spatial error regression given by (14) as below:

$$\log(y_{it}/y_{i0}) = a + \delta log y_{i0} + \rho W \mu_i + \varepsilon \quad (14)$$

where ρ is the spatial error coefficient, ε_i is a white noise error component and *W* is a spatial weighting matrix. *W* may be constructed using information on physical distance between pair wise combinations of economies in the sample or may be defined such that element w_{ij} = 1 if *i* and *j* are physically adjacent and 0 otherwise. Here, the latter approach is preferred.

Alternatively, the spatial lag model examines the extent to which regional growth rates depend on the growth rates of adjacent regions, conditional on the level of initial income:

$$\log(y_{it}/y_{i0}) = \alpha + \delta \log y_{i0} + \rho W \log(y_{it}/y_{i0}) + u_i \quad (15)$$

where ρ denotes the spatial autoregressive parameter.

Moreover, the spatial cross-regressive model allows any spatial spill-over to be reflected in the initial levels of income as follows:

$$\log(y_{it}/y_{i0}) = \alpha + \delta \log y_{i0} + \tau W \log y_{i0} + u_i \quad (16)$$

where τ represents the spatial spillovers.

Econometric Results of Spatial Models

From Table 5, it can be clearly seen that the beta coefficient is negative (β<0) and is significant in Canada during the whole period and the sub-period 1981-1990. The Beta convergence rate of Canadian provinces is 0.022 during the period 1981-2007, 0.022 during the period 1981-1990, and 0.022 during the period 2001-2007, but it is not very significant at 0.008 during the period 1991-2000. If spatial independence is considered, Beta convergence results are similar at about the 0.02 level found by the models SEM and SLM for the period 1981-2007; the SCM model had a high convergence coefficient of 0.11. This implies that the growth rate of an individual province is affected by the initial per capita income level of its neighbours. For the short sub-periods 1981-1990 and 1991-2000, the beta coefficients SEM and SCM are not very significant, but the beta coefficients calculated by the SLM model are significant for the whole period and the sub-periods. This clearly indicates the growth rate of an individual province is affected by the growth rate of its neighbours. The beta coefficient 0.05 is the highest one found by SLM while the beta coefficient calculated by the SCM model is not consistent with the other models during the short sub-period 2001-2008.

TABLE 5 Beta Coefficients of Spatial Dependency Models

Beta Coefficient						Rate			
Country	Period	Absolute	SEM	SLM	SCM	Absolute	SEM	SLM	SCM
Canada	81-07	-0.442724	-0.418118	-0.476003	-0.942018	0.0216554	0.0200551	0.023935901	0.105467506
	81-90	-0.201322	-0.094568	-0.146172	-0.092583	0.0224797	0.0099343	0.015802551	0.009715318
	91-00	-0.076575	-0.083692	-0.127604	-0.085734	0.0079666	0.0087403	0.013651183	0.008963372
	01-07	-0.144079	-0.316555	-0.071866	0.468023	0.0222253	0.0543727	0.010654166	-0.054845228
China	81-07	-0.160544	-0.050355	0.013448	-0.065913	0.0064815	0.0019136	-0.000494755	0.002525396
	81-90	-0.171818	-0.203154	-0.132257	-0.192486	0.0188522	0.0227094	0.014185969	0.021379489
	91-00	0.154364	0.144622	0.245982	0.20297	-0.014355	-0.013507	-0.021992397	-0.01847935
	01-07	-0.116753	-0.027899	-0.017103	-0.055646	0.0177358	0.0040422	0.002464421	0.008179169

Notes: SEM, SLM, SCM indicate the spatial error model, the spatial lag model, and the spatial cross-regressive model respectively. Detailed Tables of Calculation are available at http://hdl.handle.net/1866/4424.

In the case of China, there is a weak convergence of per capita provincial income during the whole period from 1981 to 2007, but it is not very significant even if it is consistent with the results of the SEM and SCM models. If provincial spatial dependency is considered, the provincial convergence rates of China are not very significant for the different periods with exception of the sub-period 1981-1990. All the estimates of Absolute Beta, SEM, SLM and SCM models strongly confirm that there is convergence for the period 1981-1990 at the different rates of 0.02, 0.022, 0.0142, 0.021 respectively, and there is divergence for the sub-period 1991-2000; there is a very weak convergence if spatial SEM, SLM and SCM Models are considered for the last sub-period. The SLM model does not support the convergence for the whole period while the other models confirm a weak but not significant convergence. This indicates that actual interaction of provinces is not very positive for the period.

Conclusion

The σ-convergence showed Canada experienced a significant provincial σ convergence for the whole period while China experienced provincial σ convergence from 1981 to 1990 and σ divergence from 1991 to 2003, with convergence starting again from 2004. If we compare the cross-country analysis, both countries seem to converge slightly, but not significantly. If we compare the weighted σ convergence that takes into account the population factor, there is significant divergence between both countries. The estimation results of β-convergence at the national level (in each country) showed that the beta coefficient is negative ($\beta<0$), and is significant in Canada during the whole period. However, the conditional "beta" divergence for the whole period is not consistent with "sigma" convergence while it is consistent with absolute beta convergence.

This spatial trend also indicates the larger provincial disparity in China and the smaller provincial disparity in Canada. The results of convergence of Canada are mostly consistent with the results of other researchers. For example, Sala-i-Martin (1996) measured absolute convergence for Canadian provinces for the period 1960-1991 and found a Beta convergence of 0.024. Colombo (1996) who estimated per capita income of

Canadian provinces over the period 1924-1994 detected there was convergence of personal income at a rate of 0.0277 during the 1950-1977 period. Shiller (2009) found that Canadian provinces converge at an annual rate of between 2.15% and 2.37%. The results of these spatial models supports the "sigma" convergence for China where we found a convergence of per capita income dispersion during the first sub period (1981-1990) and a fall in the dispersion of per capita income in the whole period 1981-2007. In the case of Canada, there is weak convergence for the whole period (1981-2007) and this is consistent with sigma convergence for this country.

The empirical convergence results as reported in the previous sections showed that regional economic development in China is more unbalanced than in Canada. There is significant gap in both countries in many indicators and both countries are very different in economic status and structure. All the results of the analyses showed that in Canada provincial disparity has gradually decreased since 1960, while in China provincial disparity decreased during the period 1981 to 1990, then increased until 2003, after which it decreased or remained at the same level. If both countries are compared, for the whole period there was divergence between both economies. It can be concluded that provincial disparity in China is greater than in Canada. The analysis indicated that most of the indicators for China have increased faster than for Canada over the whole period under study.

Bibliography

Afxentiou P.C. and A. Serletis. 1998. "Convergence across Canadian Provinces". *Canadian Journal of Regional Science* 21: 11-26

Anselin, L. 1988. *Spatial Econometrics: Methods and Models*. Dordrecht: Kluwer.

Anselin, L. 1995. "Local Indicators of Spatial Association – LISA". *Geographical Analysis* 27 (2): 93-116.

Arbia, G., R. Basile and M. Salvatore. 2003. Measuring Spatial Effects in Parametric and Nonparametric Modelling of Regional Growth and Convergence. *UNU/WIDER Project Meeting on Spatial Inequality in Development*.

Aroca, P. D Guo and G. J. D. Hewings. 2008. Spatial Convergence in China: 1952-99. in: G. Wan (ed.), *Inequality and Growth in Modern China*. Oxford: Oxford University Press.

Barro, R. and X. Sala- i-Martin. 1991. "Convergence across States and Regions". *Brooking Papers on Economic Activity* 1: 107-158.

Barro, R. and X. Sala-i-Martin. 1995. *Economic Growth*. New York: McGraw-Hill.

Coulombe. S. 1996. *Long-run Perspective on Canadian Regional Convergence*. Working Paper Number 11, May 1.

Coulombe, S. 1999. *Economic Growth and Provincial Disparity: A New View of an Old Canadian Problem*. Vancouver: C.D. Howe Institute Commentary, 3-34.

Coulombe, S, and F. C. Lee. 1993. *Provincial Economic Disparities in Canada*. Ottawa: Working Paper no. 9317E, Department of Economics, University of Ottawa.

Henley, A. 2003. On regional growth convergence in Great Britain. *The University of Wales Research Paper* 2003-3.

James, P. and J. Krieckhaus. 2008. "Canadian Regional Development: The Quest for Convergence". *Canadian Journal of Political Science* 41 (1): 187-202.

Lefebvre, M. 1994. Les provinces canadiennes et la convergence: une évaluation empirique. Ottawa: Bank of Canada Research Paper 94-10, November 1994.

McInnis, M. 1968. "The Trend of Regional Income Differentials in Canada". *Canadian Journal of Economics* 1: 440-470.

Sala-i-Martin, X. 1996. "Regional Cohesion: Evidence and Theories of Regional Growth and Convergence". *European Economic Review* 6: 1325-1352.

Wang, Z. and Z. P. Ge. 2004. "Convergence and Transition Auspice of Chinese Regional Growth". *Annals of Regional Science* 38:727–739.

Weeks M. and J. Y. Yao. 2003. "Provincial Conditional Income Convergence in China, 1953–1997: A Panel Data Approach". *Economic Review* 22 (1): 59-77.

Yao, S. and Z. Zhang. 2001. "Regional Growth in China under Economic Reforms". *The Journal of Development Studies* 38 (2): 167-86.