JOURNAL OF ECONOMIC DEVELOPMENT
Volume 39, Number 4, December 2014

GROWTH DYNAMICS AND CONDITIONAL CONVERGENCE AMONG CHINESE PROVINCES: A PANEL DATA INVESTIGATION USING SYSTEM GMM ESTIMATOR

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The paper aims at contributing to the debate on conditional convergence across Chinese provinces by using the most recent techniques of dynamics panel data models. The analysis covers twenty-nine Chinese provinces from 1995 to 2009 and is based on the estimation of growth equations using system GMM estimator. Three main results can be drawn from our empirical investigations. First, investment in physical capital and education have played an important role in promoting economic growth. Second, the hypothesis of conditional convergence is verified over the period 1995-2009. Third, Chinese provinces have converged more quickly over their steady-state level during the period 2004-2009. Finally, we suggest that the acceleration of the speed of conditional convergence in the recent years may be a consequence of the implementation of regional development programs during the 2000s.

Keywords: China, Regional Disparities, Economic Growth, Conditional Convergence, Dynamic Panel Data, System GMM
JEL classification: C33, O40, O53, P25, R11

1. INTRODUCTION

Since the early 1980s, China has made a spectacular economic catch-up. Over the past thirty years, the country has recorded an annual average growth rate of 8.5%, enabling it to become the world's second economic power[1] behind the United States. China may therefore be viewed as a model for other countries since it has been able to take off and to compete with industrialized countries despite the fact that it was still part of the Third World in the 1960s. The rapid emergence of China is closely linked to the

* I would like to thank the anonymous referee for valuable comments. All remaining errors are my own.

[1] Its Gross Domestic Product at Purchasing Power Parity amounted to 16,149.1 billion dollars in 2013 (International Monetary Fund, 2014).

shift toward an export-led growth model in the late 1970s. One of the most drastic changes involved integrating global value chains, while the economy was a near-autarky during the Mao era. However, Deng Xiaoping opted to 'let some people get rich first'. The first stage of economic reforms was therefore limited mostly to coastal provinces and cities (Fan, 2006). The model of unbalanced growth has exacerbated regional disparities in China, with coastal provinces becoming richer and more prosperous and inland provinces remaining poorer and less dynamic (Naughton, 2002).

The growing trend in regional disparities since the beginning of economic reforms in the late 1970s has led many scholars to examine the various aspects and changes affecting regional disparities. Most scholars in the field agree that regional disparities first declined between 1978 and the end of the 1980s (Jian *et al*., 1996; Dayal-Gulati and Husain, 2000; Zheng *et al*., 2000; Démurger, 2001; Lin and Liu, 2006; Li and Xu, 2008). This decrease is mainly explained by the rural reform implemented in the first stage of economic reforms, in the early 1980s. The rural reform promoted the growth of agricultural production and created job opportunities in township and village enterprises, which resulted in an increase in rural incomes (Yang, 2002; Knight *et al*., 2006). Subsequently, during the period 1990-2000, regional disparities increased continuously (Zhao and Tong, 2000; Zheng *et al*., 2000; Démurger, 2001; Cai *et al*., 2002; Lu and Wang, 2002; Kanbur and Zhang, 2005), mainly as a result of increasing disparities between coastal and inland provinces. By decomposing inequality indexes (Gini or Theil index), Yao and Zhang (2001a), and Li and Xu (2008) show that inequalities among eastern, central and western regions account for a significant share of the disparity, and have increased continuously since the 1990s. In fact, throughout the 1990s, the coastal-inland income gap increased faster than the rural-urban gap, and became the major component of overall inequality (Kanbur and Zhang, 1999; Yao and Zhang, 2001a). Nevertheless, recent studies (Li and Xu, 2008; Villaverde *et al*., 2010; Hao and Wei, 2010) show that the rate of increase in regional disparities has declined since the beginning of the 2000s. In a recent survey, the OECD (2010) also suggests that household income inequality may have started to decline in recent years.

In this paper, we propose to test whether the recent reduction in regional disparities has been accompanied by a process of economic convergence across Chinese provinces. The issue of conditional convergence in post-reform China is still not clear-cut, in so far as empirical studies produced mixed results (Chen and Fleisher, 1996; Pedroni and Yao, 2006; Li and Xu, 2008). We intend to contribute to this debate by estimating economic growth models using the most recent techniques of dynamics panel data models. Our econometric analysis involves twenty-nine Chinese provinces from 1995 to 2009. Estimation results are based on system GMM estimator in order to deal with endogeneity issues which are frequently seen in growth regressions (Bond *et al*., 2001).

The paper is organized as follows. Section 2 reviews the economic literature on regional convergence in post-reform China. Section 3 describes the data and depicts the conceptual framework which serves as a basis for choosing the variables to be included in the growth model. Section 4 develops the econometric strategy which is implemented to estimate the determinants of regional growth using system GMM estimator. Section 5 presents the results and proposes a more thorough analysis of conditional convergence over the study period. Finally, Section 6 discusses the results and concludes.

2. REGIONAL CONVERGENCE ACROSS CHINESE PROVINCES: A REVIEW

Since the pioneering work of Solow (1956), many empirical studies have focused on the convergence hypothesis. A distinction can be drawn between two types of convergence. Firstly, absolute convergence assumes that all provinces (or countries) are intrinsically the same apart from their initial capital/labour ratio. Provinces with a lower initial income have a lower capital/labour ratio than the long-run value and therefore have higher rates of return. This means that poorer provinces will grow faster and eventually catch-up with richer provinces. Secondly, conditional convergence recognizes differences between provinces in various aspects, and assumes that each province will converge toward its own steady-state level. The test of the hypothesis of conditional convergence requires that a set of variables -which differentiate the provinces- is isolated and remains constant. According to economic literature on growth and convergence (Barro and Sala-i-Martin, 1995), this set of variables includes: (i) a number of state variables, such as the stocks of physical capital and human capital; and (ii) environmental variables, such as public consumption to GDP ratio, national investment to GDP ratio, fertility rate, and changes in terms of trade.

The question of convergence across Chinese provinces since the reform era has been addressed in a number of papers, but a comparative analysis of the findings of these studies suggests that there is little consensus. Studies focusing on the immediate post-reform period (from 1978 to the mid-1990s) provide mixed and even contradictory results. Some authors validate the hypothesis of conditional convergence (Chen and Fleisher, 1996; Cai *et al*., 2002), while others give evidence of provincial divergence (Pedroni and Yao, 2006). Besides, some studies that reject the hypothesis of conditional convergence still find evidence of convergence club.[2] In this line, Yao and Zhang (2001b) find evidence of provincial convergence within three clubs of growth during the period 1978-1995: coastal provinces, central provinces and western provinces. Weeks and Yao (2003) also find that coastal and inland provinces are converging toward their own steady-state level during the period 1978-1997. Finally, analyses based on more recent data (until the mid-2000s) tend to validate the hypothesis of conditional convergence across Chinese provinces (Zou and Zhou, 2007; Li and Xu, 2008).

The lack of consensus over the convergence issue may be linked to a number of

[2] The concept of “convergence club” is based on the idea that even if convergence is not verified at the global level, regions belonging to the same group can converge provided they share the same structural characteristics. (Berthélemy, 2006)

factors. First, the studies referred to above are not based on the same data sets and do not cover exactly the same periods. Second, official data on China are controversial. In particular, data covering the period that immediately has followed the beginning of economic reforms may suffer from consistency and reliability issues (Maddison, 1998; Rawski, 2001). Third, as emphasized by Knight "evidence of absolute divergence might be an artefact," (2013, p. 11), because official data exclude rural-urban migrants to calculate provincial population. As a consequence, "this approach overstates the GDP per capita in the richer provinces that attract migrants" resulting in an exaggerated GDP per capita growth rate in these provinces (Knight, 2013, p. 11). Fourth, the choice of control variables often depends on data availability. The differences in economic growth between Chinese provinces may be the result of a wide range of factors. Therefore, if variables accounting for the specific characteristics of provinces are missing, the hypothesis of conditional convergence may be invalidated. Fifth, if some explanatory variables are endogenous with respect to economic growth, the results may be biased (Nickell, 1981). To address these concerns, this paper proposes to analyze the hypothesis of conditional convergence using the system GMM estimator (Blundel and Bond, 1998) so as to obtain results that are adjusted for endogeneity. Besides, the econometric estimation will be useful not only for testing the hypothesis of conditional convergence but also for identifying the driving forces of regional economic growth in China.

3. GROWTH MODEL AND DATA

3.1. Conceptual Framework: The Determinants of Economic Growth

As mentioned by Ding and Knight (2011), there is no single explicit theoretical framework that constitutes a base for empirical work on economic growth. A number of studies rely on the neoclassical model (Solow, 1956) and its extension (e.g., Mankiw *et al.*, 1992), whereas a growing number of empirical works implement informal growth regressions which allow to include a larger set of explanatory variables (Barro, 1991; Barro and Sala-i-Martin, 1995).

In accordance with Durlauf *et al.* (2005), the growth equation that we have chosen to estimate can be written as follows:

$$y_{i,t} = \beta \ln Y_{i,0} + \Psi X_{i,t} + \pi Z_{i,t} + \varepsilon_{i,t} \, , \tag{1}$$

where y is the growth rate of GDP per capita, X variables stand for traditional determinants of growth in accordance with models of conditional convergence (Solow, 1956; Mankiw *et al.*, 1992), and Z variables account for additional determinants from endogenous growth models (Romer, 1986; Barro, 1991).

In Solow growth model, the initial level of income is considered as a strong predictor of differences in growth rates across countries or regions. All other things being equal, provinces with a lower per capita GDP are predicted to grow at a faster rate than the richest provinces.[3] As a result, under the hypothesis of conditional convergence, the associated $\hat{\beta}$ coefficient is predicted to be significant and negative (Solow, 1956; Barro and Sala-i-Martin, 1995). The convergence analysis can be completed by calculating two additional parameters. The first one is the "speed on convergence" ($b = -\ln(1 + T\hat{\beta})/T$), which represents the rate at which an economy is getting closer to its steady-state level of income every year. The second one is the "half-life" $[\tau = -\ln(2)/\ln(1+\hat{\beta})]$, accounting for the time required for an economy to cover half the distance from its steady-state level.

Physical capital accumulation is an important determinant of growth in both Solow and endogenous growth models (Romer, 1986).[4] Firms can accumulate know-how through capital accumulation and the free flow of information. Consequently, some investments can produce growing returns and promote economic growth.

Empirical studies also emphasize the influence of population growth on economic growth. The underlying idea is that a rise in fertility rate (proxied by the natural growth rate) may be perceived as an opportunity cost of productive activities. If population increases, a part of national investment will be used to provide capital for new workers instead of raising the level of capital per worker (Barro, 1998). As a consequence, this variable is assumed to have a negative impact on economic growth.

The augmented Solow model (Mankiw *et al.*, 1992) shows that human capital can favourably influence growth. This broad concept refers to the stock of skills, knowledge, personality and physical health that can be used by a worker to be more efficient and more productive (Lucas, 1988). More specifically, education can increase labor productivity and therefore lead to a higher equilibrium level of output (Mankiw *et al.*, 1992). In theories of endogenous growth, education is also seen as a way to increase the innovative capacity of the economy that promotes growth (Lucas, 1988; Romer, 1990).

In the literature on economic growth, there is no consensus on the role of public spending which seems to play an unclear role. Barro (1990) showed that public spending can promote growth by improving corporate productivity through public infrastructures and human capital. However, the increase in taxation resulting from the funding of public expenditures may have a negative impact on growth. Therefore, the coefficient of the variable is expected to be either positive or negative, depending on which effect is stronger.

Another potential determinant of economic growth that has been highlighted in the literature is the existence of adequate infrastructures (Aschauer, 1990; Démurger, 2001;

[3] Due to the law of diminishing marginal returns on capital.

[4] Romer (1990) also emphasized the role of innovation in endogenous growth. Unfortunately, research-and-development expenditures were not taken into account since the relevant data were not available.

Egert *et al*., 2009). Infrastructures can provide positive externalities by promoting labour mobility, exchange of goods and services, and information flow.

3.2. Data and Variables

The original dataset used in this study consists of a panel of twenty-nine Chinese provinces with annual data for the period 1995-2009.[5] The data are drawn from various editions of the *China Statistical Yearbook* published by the National Bureau of Statistics of China. The quality and reliability of Chinese official data have been largely disputed in the literature (Maddison, 1998; Rawski, 2001; Holz, 2006). However, there is now a rough consensus on the fact that despite of some errors and statistical discrepancies, official statistics can be considered as reliable (Holz, 2006; Chow, 2006).[6]

Based on available data at the provincial level from the official Yearbooks, we have constructed several variables that correspond to the different determinants of economic growth detailed in section 3.1.

First, the initial level of income is proxied by the logarithm of GDP per capita of province i at the beginning of each period (*Initial level of income*). Second, physical capital accumulation is integrated to our analysis via the investment rate, calculated as the share of gross fixed capital formation in GDP (*Investment*). Third, the impact of population growth is taken into account via the variable *Population*, which is equal to $n+g+\delta$. n accounts for the natural growth rate of each province. g and δ respectively represent the rate of technical progress and the rate of depreciation of physical and human capital. In their seminal work, Mankiw *et al*. (1992) assume that $g+\delta=0.05$. The growth literature generally remains close to this figure, since δ is often set at 0.04 and g at 0.02 (Lipschitz *et al*., 2011). Nevertheless, some studies emphasize that these rates are below international standards for transitional economies (Wu, 2004; Bosworth and Collins, 2008). In line with Bosworth and Collins' (2008) estimations, we assume that in the case of China, the rate of technical progress g equals 0.04 and the depreciation rate is $\delta=0.06$. Fourth, we include a variable accounting for human capital. In most empirical studies, it is proxied by average years of schooling or by educational enrolment rates (Barro, 1991; Mankiw *et al*., 1992; Islam, 1995). In China, the main difference in education between provinces is the enrolment rate in higher education (Fleisher and Chen, 1997; Yao, 2006). As a result, we consider that our human capital variable should reflect the propensity for secondary school students to be

[5] China is administratively divided into 31 provinces, municipalities and autonomous regions. Tibet is excluded from the analysis because of missing data over several years. Data concerning Chongqing, a province created in 1997, were incorporated in the data for Sichuan.

[6] Chow (2006) relies on three arguments to stand for the reliability of Chinese official data: (i) the assigned responsability of the officials preparing the data; (ii) the use of official data in government decision-making; and (ii) their use in many empirical articles that have been published in refereed journals.

enrolled in higher education. Following Yao (2006) and Ding and Knight (2011), the ratio of the number of students enrolled in higher education over the number of students enrolled in secondary education is used to represent human capital (*Education*).[7] Fifth, we try to take into account State intervention through the variable *Public expenditures* which represents the share of public expenditures in total GDP of each province. Sixth, the development level of infrastructures is proxied by railway density, which represents the ratio of the number of railway kilometres to provincial population (*Infrastructures*).[8] All nominal values are adjusted for inflation based on provincial consumer price indexes (at 1994 prices) so as to take account of price changes in each Chinese province.

3.3. Specification of the Time Intervals of the Dataset

The Im-Pesaran-Shin panel unit root test (Im *et al*., 2003) is applied to check the stationarity of the annual series of each variable between 1995 and 2009. The results are presented in Table A1 in the Appendix and reveal that excepted for *GDP per capita growth rate* and *Education*, the null hypothesis of non-stationarity cannot be rejected. The non-stationarity of some variables supports our choice to not directly use annual data. We rather opt for non-overlapping time intervals, which are widely used in the cross-country growth literature (e.g., Islam, 1995; Bond *et al*., 2001; Ding and Knight, 2011).

We therefore choose to implement our panel data analysis for the twenty-nine Chinese provinces over five three-year average periods (1995-1997, 1998-2000, 2001-2003, 2004-2006 and 2007-2009).[9] The use of three-year averages has several advantages, thought there is no consensus on the determination of the appropriate time intervals (Temple, 1999). First, the use of averages over several years decreases the influence of short-term shocks and business cycles on economic activity, and reveals long-run relationships (Ding and Knight, 2011). Therefore, it is a way to avoid the problem of non-stationarity which could have produced biased results (regression fallacy). Second, compared to five-year or fifteen-year intervals, the use of three-year intervals allows to keep a sufficient number of observations to use the time dimension of panel data.

[7] We also attempted to take into account health conditions through the ratio of the number of hospital beds to provincial population. This choice was conditioned by the lack of health data in the long term. For instance, data relating to life expectancy or public spending on health are not available for each province over the period of study. This variable was removed from the analysis due to multicolinearity problem.

[8] We also tried to capture the influence of commercial openness, via the ratio of exportations to GDP, in line with Wu (2004). However, this variable was removed from the analysis due to its strong correlation with other control variables.

[9] Three-year average periods have also been used in empirical studies, such as Brun *et al*. (2002), Madariaga and Poncet (2007) and Li and Xu (2008).

Table A2 in the Appendix provides a summary description of the construction of the variables, and also reports descriptive statistics for each variable over the whole period and over each time interval. Moreover, for the purpose of the econometric analysis, all explanatory variables are expressed as logarithms so as to facilitate the interpretation of the associated coefficients.

4. ECONOMETRIC STRATEGY

The panel estimation can be first implemented using a fixed-effects model (FEM) which incorporates individual-specific (time-invariant) effect (δ_i) and time-specific (individual-invariant) effect (λ_t):

$$y_{i,t} = \alpha_1 + \alpha_2 x_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}\,, \qquad (2)$$

where the dependent variable y for province i in year t, is explained by a set of independent variables $x_{i,t}$ and by unobservable characteristics: province-specific (δ_i) and time-specific (λ_t).

The fixed-effects estimator (also called within estimator) is obtained by ordinary least squares (OLS) on the deviations from the means of each individual. However, this estimator can provide biased estimations if the number of time periods is small, and if the lagged value of the dependent variable $y_{i,t-1}$ is correlated with the individual effects δ_i (Matyas and Sevestre, 2008). In particular, the estimation of growth regression may raise several problems (Bond *et al.*, 2001). First, explanatory variables may be endogenous because of reverse causality or measurement errors. The within estimator has been shown to produce estimations of parameters that are inconsistent and biased downward in presence of endogeneity (Nickell, 1981). Second, omitted variables can bias the estimation. In our case, the omission of characteristic variables may lead to invalidate the conditional convergence hypothesis.

To address these issues, Holtz-Eakin *et al.* (1988) and Arellano and Bond (1991) suggest to estimate dynamic panel data models using the generalized method of moments (GMM). GMM includes the lagged endogenous variable as an explanatory variable:

$$y_{i,t} = \alpha_1 + \alpha_2 y_{i,t-1} + \alpha_3 x_{i,t} + \delta_i + \lambda_t + \varepsilon_{i,t}\,. \qquad (3)$$

Those authors propose to estimate the regression equation with a first-differentiated GMM estimator. For each period, it is necessary to first-differentiate the equation in order to eliminate individual specific effects:

$$y_{i,t} - y_{i,t-1} = \alpha_1 (y_{i,t-1} - y_{i,t-2}) + \alpha_2 (x_{i,t} - x_{i,t-1}) + (\lambda_t - \lambda_{t-1}) + (\varepsilon_{i,t} - \varepsilon_{i,t-1}) \ . \quad (4)$$

By construction, ($y_{i,t-1} - y_{i,t-2}$) is correlated with the error term ($\varepsilon_{i,t} - \varepsilon_{i,t-1}$). As a consequence, it is necessary to resort to instrumental variables techniques (for $t \geq 2$). Arellano and Bond (1991) suggest to use the lagged levels of the lagged endogenous variable $y_{i,t-1}$ as instruments for ($y_{i,t-1} - y_{i,t-2}$), and the lagged levels of the explanatory variables $x_{i,t}$ as instruments for ($x_{i,t} - x_{i,t-1}$). Nevertheless, there are limitations to this approach. For instance, Blundell and Bond (1998) point out that the first-differentiated GMM estimator may provide biased results in the case of finite sample size, and that the lagged levels of the variables cannot be considered as reliable instruments when the dependent and the independent variables are continuous.

To obviate the weak instrument problem, Arellano and Bover (1995) and Blundell and Bond (1998) suggest a second method based on the system GMM estimator. This estimator combines: (i) the standard set of equations in first-differences, ($y_{i,t-1} - y_{i,t-2}$) and ($x_{i,t} - x_{i,t-1}$) variables, with suitably lagged levels as instruments, (ii) with an additional set of equations in levels, $y_{i,t-1}$ and $x_{i,t}$ variables, with suitably lagged first-differences as instruments. Blundell and Bond (1998) have also developed a two-step GMM estimator to address the problem of heteroscedasticity. First, they suggest to get the residuals from the first-step estimation. Second, they recommend to use them in order to perform a robust estimation of the variance-covariance matrix. Using Monte Carlo simulations, Blundell and Bond (1998) show that the two-step estimation method is asymptotically more efficient than the first step method. However, they also underline that the two-step estimation may produce downward biased results when using finite samples. To eliminate this potential bias, Windmeijer (2005) proposes a finite sample correction for the variance-covariance matrix when using the two-step GMM estimator.

The consistency of the system GMM estimator relies on two hypotheses. First, the set of instrumental variables must be valid, i.e., not correlated with the error terms. This hypothesis is tested using Sargan/Hansen test of overidentifying restrictions.[10] Second, the absence of second-order autocorrelation (AR2) in residuals must be verified, while a negative first-order autocorrelation (AR1) may be detected. This second hypothesis is tested using Arellano-Bond tests for AR1 and AR2.

Roodman (2009) shows that using too many instruments can produce biased results in GMM estimation.[11] Although the empirical literature provides little evidence on the

[10] The Hansen test is implemented instead of the Sargan test when the estimations are adjusted for heteroscedasticity.

[11] In particular, Sargan and Hansen tests can be weakened by the use of too many instruments (Roodman, 2009).

maximum number of instruments to use, the minimum standard is to have less instruments than individuals (Roodman, 2009). Arellano and Bover (1995) also suggest to use only the most recent difference as an instrument for the level specification of explanatory variables, because other lagged first-differences would result in redundant moment conditions. In this line, we limit the number of lags for both the dependent and explanatory variables to one.[12] Taking all this into consideration, we estimate our growth equation using two-step GMM estimator with Windmeijer's correction method for the variance-covariance matrix.[13]

5. RESULTS

Explanatory variables are progressively introduced into the growth regression in order to check the stability of our results. Model 1 is derived from Solow (1956, p. 70) and explains the growth rate of per capita GDP by the initial per capita GDP, the accumulation of physical capital and the population growth. Model 2 represents the augmented Solow model proposed by Mankiw *et al*. (1992), which includes a variable accounting for human capital. The impact of public expenditures on growth is integrated into the analysis in model 3. Finally, model 4 also includes a variable accounting for the infrastructure level. Estimations results of the four growth models using system GMM estimator are presented in Table 1.

5.1. Determinants of Provincial Economic Growth

The Hansen test shows that we cannot reject the null hypothesis that the error term is uncorrelated with the instruments for models 1 to 3. For these models, the validity of the instrumental variables of the regression is therefore confirmed. Arellano-Bond tests indicate the presence of a negative first-order autocorrelation for the first three models, while we cannot reject the null hypothesis that there is no autocorrelation of order 2 in each of the four models. In view of the results of both Hansen and Arellano-Bond tests, we will only focus on the parameter estimates resulting from models 1 to 3, for which the validity is confirmed.

[12] These restrictions enable us to keep the number of instruments for below that of regions, as recommended by Roodman (2009).

[13] Results are obtained using STATA 11 software.

Table 1. Determinants of the Growth Rate of Regional GDP per Capita in China (1995-2009) Using System GMM Estimator

Variables	SYS-GMM Model 1	SYS-GMM Model 2	SYS-GMM Model 3	SYS-GMM Model 4
GDP_{t-1}	0.0457	0.1884	-0.0285	-0.0388
	(0.24)	(1.03)	(-0.15)	(-0.19)
Initial level of income	**-0.0267****	**-0.0432*****	**-0.0413***	**-0.0364***
	(-2.40)	(-2.81)	(-1.80)	(-1.88)
Population	**-1.6971*****	**-1.3181*****	**-1.0033****	-0.5765
	(-3.77)	(-2.89)	(-2.47)	(-1.25)
Investment	**0.1390*****	0.0283	**0.1888****	**0.1075***
	(3.01)	(0.51)	(2.33)	(1.92)
Education	-	**0.0376****	**0.0325***	0.0594
		(2.41)	(1.94)	(1.67)
Public expenditures	-	-	**-0.0914****	**-0.1388***
			(-2.30)	(-1.87)
Infrastructures	-	-	-	0.0464
				(1.31)
Intercept	**-3.3498*****	**-2.3841*****	**-1.7223****	**-0.4684***
	(-2.36)	(-2.49)	(-2.13)	(1.98)
Nb of observations	116	116	116	116
Nb of individuals	29	29	29	29
Nb of instruments	9	11	13	15
Hansen test of overidentifying restrictions	3.67 (0.452)	8.74 (0.12)	6.13 (0.19)	17.96 (0.012)
Arellano-Bond test for AR(1)	-2.15	-2.60	-2.03	-1.28
	(0.031)	(0.009)	(0.043)	(0.199)
Arellano-Bond test for AR(2)	-0.28	-0.17	-1.02	-0.86
	(0.783)	(0.864)	(0.307)	(0.391)

Source: Author's calculation, based on *China Statistical Yearbook* (1996-2010).

Notes: Three-year intervals data for 29 provinces (1995-97; 1998-2000; 2001-03; 2004-06; 2007-09); Two-step system GMM estimations with Windmeijer's (2005) finite-sample correction for the variance-covariance matrix; Robust standard errors into brackets for GMM estimates, p-value into brackets for Hansen and Arellano-Bond tests. Level of statistical significance: 1 %***, 5 %**, and 10 %*. Time dummies are not reported.

Barriers to Regional Growth

First, estimations of models 1 to 3 show that population growth has a negative impact on economic growth. It means that provinces with a higher population growth rate tend to record a significantly lower growth of their GDP per capita (at the 5% level).

This result is in line with Solow (1956, p. 90), which supposes that a slower population growth results in a higher equilibrium level of both the output and capital stock per worker. In the late 1970, China has realized that the important growth of its population may constitute a threat to its economics development and decided to implement the "one-child policy". Some researchers, such as Ding and Knight (2011), emphasize that despite the controversy over the humanity of this tightened demographic policy, it has had a positive impact on the growth of Chinese GDP per capita through the reduction of resource pressures.

Second, results of model 3 underline that public expenditures have a detrimental effect on the dependant variable, since the coefficient associated to the variable is negative and significant at the 5% level. This result may be explained by the fact that public intervention can generate a crowding-out effect and inhibit private investment. In the case of China, Gipouloux (1998) and Catin *et al*. (2005) show that a strong government intervention acts as a deterrent on foreign direct investments. This result suggests that reducing state intervention and improving the degree of marketization may have a positive impact on growth and regional disparities. To deepen the analysis, it could be interesting to exclude certain items of public expenditures (such as military expenditures) in order to see whether government expenditures on human capital and infrastructures, for their part, have a positive impact on growth.

Engines of Regional Growth

In both models 1 and 3, the coefficient associated to the share of investment in GDP is significantly positive, respectively at the 1% and 5% level. The accumulation of physical capital can therefore be considered as an engine of regional growth over the period 1995-2009. According to model 1, a 1% increase in the investment rate is associated with a 0.14% rise in the growth rate of GDP per capita. This figure is higher than that of 0.073 estimated by Cai *et al*. (2002) for the 1978-1998 period, and of 0.072 found by Li and Xu (2008) between 1991-2005. However, it is quite similar to the 0.151 estimated by Ding and Knight (2011) using panel data for the period 1978-2006. In the short and medium term, the crucial role of physical capital accumulation in the Chinese growth is largely acknowledged (Wu, 2004). Nevertheless, some scholars raise doubts about the sustainability of this economic growth model in the long run (Gaulard, 2009).

The propensity of secondary school students to be enrolled in higher education is also significantly associated with higher regional economic growth in model 2 and 3 (at the 5 and 10% level). It means that provinces that provide better educational environment and better access to institutions of higher education tend to record higher growth rate of their GDP per capita. The positive impact of education on regional growth in China is consistent with the findings of Fleisher and Chen (1996), Cai *et al*. (2002), and Li and Xu (2008). More specifically, the important contribution of higher education to growth has been emphasized by Chi (2008) and Ding and Knight (2011), who find that tertiary education has a bigger impact on both GDP growth and fixed investment than primary and secondary education. All in all, this result suggests that the improvement of education standards is a key factor in promoting the reduction of regional disparities.

Conditional Convergence of the Chinese Provinces

Last but not least, in each of the three models, the coefficient associated to the initial level of per capita GDP is negative and significant (at least at the 10% level). This negative association indicates that among provinces that share the same structural characteristics, those which were initially richer have recorded slower growth rate over the period, whereas the growth rate of poorer provinces has been higher. In other words, when we control for the previous set of variables, the hypothesis of conditional convergence is validated during the period 1995-2009. This result means that each province is converging toward its own steady-state level.

Moreover, based on the estimated $\hat{\beta}$ coefficients, the speed of convergence ranges from 3.4% in model 1, to 7% in model 2.[14] This speed of convergence is higher than the 2 to 3% usually found in cross-section studies (Barro and Sala-i-Martin, 1991, 1992). However, these figures are consistent with international evidence on regional convergence that show that the speed of convergence across regions is commonly faster in developing countries than in industrialized countries (Purfield, 2006), but also when panel data are used (Caselli *et al*., 1996). For example, Barro and Sala-i-Martin (1991) and Sala-i-Martin (1994) estimate that the speed of conditional convergence between the regions of the United States, those of Europe and those in Japan is close to 2%. In the developing world, Nosbusch (1999) find that the speed of conditional convergence across Indian States ranges from 7% to 36% depending on the model specification. Compared to previous studies on conditional convergence across Chinese provinces, this figure is higher than the one calculated by Zou and Zhou (2007), amounting to 1.64% between 1981 and 2004. However, it is more consistent with the 8% speed of convergence estimated by Madariaga and Poncet (2007) using spatial system GMM estimator over the period 1990-2002. In fact, the correction of endogeneity problems using system GMM method leads to better estimate the speed of conditional convergence of Chinese provinces, with a higher speed than the one obtained using the fixed effect estimator (between 1.95% and 5.4%, see Table A3 in the Appendix). As for the half-life, it ranges from 25.6 years in model 1 to 15.7 in model 2. On this basis, Chinese provinces take approximately 26 years (respectively 16 years) to close half the

[14] Such differences in the speed of conditional convergence according to the specification of the model are commonly observed in growth empirics, such as Caselli *et al*. (1996). They are mainly due to the variables included into the growth equation and seem to be almost inevitable since there is no consensus on the theoretical framework that constitute a base for empirical work on economic growth (Ding and Knight; 2011).

gap between their current level of income and their steady-state level. All in all, our results emphasize that each Chinese provinces is converging towards its steady-state level of income at a relatively fast pace.

5.2. Robustness Check

In order to test the robustness of our different specifications, we try to examine whether our results are stable (i.e., significance and magnitude of coefficients) when we use annual data instead of three-year intervals. We therefore re-estimate models 1 to 4 using a panel of twenty-nine provinces over fifteen years. Results of the estimations using annual series are presented in Table A4 in the Appendix. The Hansen test and the Arellano-Bond tests reveal that our estimates are valid only for models 1 and 2.

Surprisingly, the coefficient associated to the variable *Population* is not significant when we use annual data. As for the variable *Investment*, the associated coefficient in the Solow growth model is positive and significant at the 10% level. Nevertheless, the magnitude of the coefficient (0.0995) is lower than the one observed in the estimation using three-year intervals (0.139). The propensity for secondary school students to be enrolled in higher education is also significantly associated with a higher GDP per capita growth rate (at the 10% level), but its impact is lower compared to that estimated using three-year average setup (0.0249 versus 0.0376). All in all, the differences in the magnitude of the estimated coefficients may be explained by the fact that with yearly data, the influence of temporary factors associated with business cycles is not alleviated and it is therefore more difficult to point out long-term relationship (as emphasized by the non-stationarity of these variables, see Table A2 in the Appendix).

Last but not least, the hypothesis of conditional convergence is still confirmed at the 10% level. The speed of convergence is estimated to be 6.2% in model 1 and 8.7% in model 2. This figures are slightly higher than the ones obtained using time intervals, which can be explained by the specification of the initial level of income variable: with annual data, the initial GDP per capita refers to 1995, whereas with three-year average data the reference is GDP per capita at the beginning of each period (i.e., 1995; 1998; 2001; 2004; 2007).

To conclude, our results seem to been robust to the time interval used in so far as variables have the expected sign and are significant using both specifications (apart from the variable *Population*).

Table 2. Determinants of the Growth Rate of Regional GDP per Capita in China (1995-2009) Using System GMM Estimator, with a Focus on Conditional Convergence

Variables	SYS-GMM Model 1	SYS-GMM Model 2	SYS-GMM Model 3	SYS-GMM Model 4
GDP_{t-1}	-0.1932	0.0699	-0.1513	-0.1080
	(-0.83)	(0.35)	(-0.84)	(-0.57)
Initial level of income $_1$	**-0.0316****	**-0.0526****	**-0.0349****	-0.0374
	(-2.11)	(-2.25)	(-2.45)	(-1.18)
Initial level of income $_2$	**-0.0364****	**-0.0598****	**-0.0388****	-0.0413
	(-2.30)	(-2.32)	(-2.55)	(-1.28)
Population	**-1.4799*****	**-1.3319****	**-0.9729****	**-0.8539***
	(-3.13)	(-2.65)	(-2.43)	(-1.76)
Investment	**0.1031***	0.0120	0.1074	0.0516
	(1.83)	(0.17)	(0.97)	(0.77)
Education	-	**0.0384***	0.0186	0.0339
		(1.97)	(1.30)	(1.09)
Public expenditures	-	-	-0.0349	-0.0537
			(-0.95)	(-0.91)
Infrastructures	-	-	-	0.0220
				(0.68)
Intercept	**-2.8015*****	**-2.3319****	**-1.6688****	-1.2182
	(-2.78)	(-2.43)	(-2.13)	(-1.14)
Nb of observations	116	116	116	116
Nb of individuals	29	29	29	29
Nb of instruments	11	13	15	17
Hansen test of overidentifying	5.23	3.57	-0.84	19.40
restrictions	(0.156)	(0.312)	(0.401)	(0.013)
Arellano-Bond test for AR(1)	-2.42	-1.66	-1.36	-1.06
	(0.015)	(0.090)	(0.174)	(0.287)
Arellano-Bond test for AR(2)	-1.06	-0.83	17.20	-1.28
	(0.288)	(0.406)	(0.016)	(0.202)

Source: Author's calculation, based on *China Statistical Yearbook* (1996-2010).

Notes: Three-year intervals data for 29 provinces (1995-97; 1998-2000; 2001-03; 2004-06; 2007-09); Two-step system GMM estimations with Windmeijer's (2005) finite-sample correction for the variance-covariance matrix; *Initial level of income*$_1$ refers to data from 1995 to 2003 and *Initial level of income*$_2$ refers to data from 2004 to 2009; Robust standard errors into brackets for GMM estimates, p-value into brackets for Hansen and Arellano-Bond tests. Level of statistical significance: 1 %***, 5 %**, and 10 %*. Time dummies are not reported.

5.3. A More Thorough Analysis of Conditional Convergence

In an attempt to refine the analysis of conditional convergence, the variable accounting for the initial per capita GDP is decomposed into two variables. The first variable (*Initial level of income*$_1$) is obtained by multiplying the initial level of income by a dummy variable which takes the value of 1 if the period under study lies between 1995 to 2003, and 0 otherwise. In the same way, the second variable (*Initial level of income*$_2$) is obtained by multiplying the initial per capita GDP by a dummy variable equal to 1 if the period under study is comprised between 2004 to 2009, and 0 otherwise. The division of the variable accounting for initial income will allow us to determine whether the hypothesis of conditional convergence is validated for the entire period, or only for one sub-period. If appropriate, it will also allow us to see if the speed of convergence is higher during either of the two sub-periods. Estimation results for models 1 to 4 with a focus on conditional convergence are reported in Table 2. The Hansen and Arellano-Bond tests confirm the validity of our estimates only for models 1 and 2. Consequently, our comments will only focus on results from the first two models.

Regardless of the model applied, the coefficients of both initial income variables are negative and significant at the 5% level. The hypothesis of conditional convergence is therefore validated for both sub-periods. It is worth noting that the coefficient for the second sub-period (2004 to 2009) is higher than that of the first sub-period (1995-2003). On the basis of Solow model (model 1), the speed of convergence is 3.7% in the first sub-period, and 4.1% in the second sub-period. Estimation of the augmented Solow model (model 2) leads to a higher speed of convergence: 7.1% from 1995 to 2003, and 7.4% from 2004 to 2009. All in all, this result indicates that Chinese provinces have converged more quickly over the most recent period.

6. DISCUSSION AND CONCLUSION

The objective of this paper was to contribute to the debate on conditional convergence across Chinese provinces by taking into account the problems of measurement errors, omitted variables and reverse causality, which represent potential sources of endogeneity. The existence of these problems may produce biased results and lead to invalidate the convergence hypothesis (Nickell, 1981; Bond *et al*., 2001). In order to address the endogeneity issue which is often observed in growth empirics, we propose to test the conditional convergence hypothesis using the most recent techniques of dynamics panel data models. Our econometric analysis is based on various editions of *China Statistical Yearbook* and considers panel data covering twenty-nine Chinese provinces during five three-year periods from 1995 to 2009. We estimate growth equations derived from Durlauf *et al*. (2005) using two-step system GMM estimator (Blundell and Bond, 1998) with Windmeijer's (2005) finite-sample correction for the variance-covariance matrix.

The empirical investigations conducted as part of this research bring two main results as regard the determinants of provincial economic growth in China: (i) population growth and the share of public expenditures in GDP have a negative impact on economic growth; (ii) investment in physical capital and education have played an important role in promoting economic growth and may be considered as a means of reducing regional disparities. The econometric analysis also allows us to bring interesting results on the convergence issue: (i) the hypothesis of conditional convergence is verified during the period 1995-2009, which means that each Chinese province is converging toward its steady-state level of income; (ii) the speed of convergence is relatively high (between 3.4% and 7% depending on the model adopted) but consistent with the rate estimated by Poncet and Madariaga (2007); (iii) the speed of convergence is found to be faster during the period 2004-2009 (compared to the period 1995-2003), which indicates that Chinese provinces have converged more quickly over the most recent period.

The increase in the speed of convergence over the most recent period may be related to the recent efforts of Chinese authorities to rebalance development between provinces. Since the beginning of the 2000s, Chinese government is increasingly concerned about the explosion of inequalities, which represents a potential threat to social cohesion, political stability and sustainable development (Renard, 2002). In an attempt to reduce the regional gap, several development programs have been created. First, the “Great Western Development” strategy (*xibu da kaifa*) has been launched in 2000. The objective is to promote the regional development of western provinces, primarily by creating transport infrastructures. Although performances have been mixed due to the great socioeconomic diversity of provinces in this group (Goodman, 2004), some western provinces have benefited from this program. At the end of the 2000s, Inner Mongolia has become one of the most prosperous provinces of China, and the “west triangle economic zone” between the cities of Chongqing, Chengdu (in Sichuan province) and Xi’an (in Shaanxi province) is one of the most dynamic centres of growth. Second, the program for “revitalizing old industrial bases in northeast China” (*zhenxing dongbei lao gongye jidi*) has been implemented in 2003. It aims at creating new industrial centres in the three provinces of old Manchuria. In particular, Liaoning and Jilin have been able to move toward sectors with high future potential (such as automobile, aerospace, hi-tech and chemical and pharmaceutical industries). Third, since 2006 the “rise of central China” plan (*zongbu jueqi jihu*) has led to an important increase in per capita GDP of central provinces. In particular, Hubei and Hunan have recorded growth rates above the national average. All in all, changes in the spatial polarization of growth appear to be on the way since the beginning of the 21st century. While the open-door policy implemented in 1978 contributed to increase the gap between prosperous coastal provinces and poorer inland provinces (Naughton, 2002), today coastal provinces are no longer the only Chinese growth poles. Certain inland provinces are rapidly growing, which may partially explain the acceleration of the convergence process during the late 2000s.

Furthermore, the recent Twelfth Five-Year Plan (2012-2017) has emphasized the need to tackle the issue of unbalanced regional development, widely recognized as a significant threat to the sustainability of economic development. To achieve this aim, the plan proposes guidelines to advance regional integration and promote urbanization. The eastern region is still expected to lead economic development. In addition, support will be given to industries and ecologically-oriented projects in western provinces, such as Sichuan, Yunnan, Gansu, Qinghai and Xinjiang. In north-east China, industries will be revitalized and the modern industrial system improved. The development of central provinces will be energized, while the role of city clusters within the region will be strengthened. China also plans to stimulate the growth of development priority zones (DPZs) by implementing policies with specific guidance for each of the four regions. This set of policies may serve to boost and rebalance growth across the country, particularly in late-developing provinces. However, it is likely that China will also need to implement institutional reforms (such as reforming the *hukou* system) to enhance regional spillovers and to move toward a more balanced and sustainable economic development.

APPENDIX

Table A1. Im-Pesaran-Shin Panel Unit Root Test for the Annual Series of Each Variable

Variables	t-bar statistics	p-value
GDP per capita growth rate	-2.442	0.068
Population	-2.161	0.517
Investment	-1.731	0.992
Education	-2.648	0.005
Public expenditures	-2.108	0.631
Infrastructures	-1.939	0.895

Source: Author's calculations, based on China Statistical Yearbooks (1996-2010).

Notes: Variables are demeaned. For all variables, both the trend and the constant are included.

Table A2. Definition and Descriptive Statistics of the Variables Over the Whole Period and Over Each Sub-sample Periods.

Variable	Definition	Full-sample	Sub-sample periods				
		1995-2009	95-97	98-00	01-03	04-06	07-09
		Dependent variable					
Economic growth	Growth rate of real provincial GDP per capita	0.1051 (0.05)	0.0711 (0.033)	0.0750 (0.021)	0.1041 (0.020)	0.1518 (0.041)	0.1239 (0.036)

	Independent variables						
Initial level of income	Logarithm of real GDP per capita at the beginning of the period (1994 RMB)	4650.43 (3052.94)	4650.43 (3052.94)	5823.92 (4028.52)	7359.74 (5254.11)	10626.17 (7699.57)	15416.48 (9594.90)
Population	Population natural growth rate (n = birth rate – death rate) + rate of technical progress (g = 0.04) + depreciation rate (δ = 0.06)	0.1065 (0.004)	0.1087 (0.004)	0.1071 (0.004)	0.1057 (0.004)	0.1054 (0.003)	0.1054 (0.003)
Investment	Provincial gross fixed capital formation / provincial GDP	0.4290 (0.12)	0.3488 (0.086)	0.3767 (0.083)	0.4069 (0.094)	0.4733 (0.091)	0.5395 (0.110)
Education	Students enrolled in higher education / Students enrolled in regular secondary education	0.1601 (0.165)	0.0660 (0.059)	0.0795 (0.077)	0.1349 (0.111)	0.2181 (0.174)	0.3017 (0.218)
Public expenditures	Provincial public expenditures / provincial GDP	0.1498 (0.07)	0.1040 (0.036)	0.1263 (0.046)	0.1583 (0.064)	0.1629 (0.062)	0.2273 (0.078)
Infrastructures	Provincial railway kilometres / provincial population	0.0001 (0.0001)	0.00007 (0.0001)	0.00007 (0.0001)	0.00008 (0.0001)	0.00008 (0.0001)	0.00008 (0.0001)

Source: Author's calculations, based on *China Statistical Yearbook* (1996-2010).
Note: Standard deviation into brackets.

Table A3. Determinants of the Growth Rate of Regional GDP per Capita in China (1995-2009) using Fixed-Effect Estimator

Variables	Fixed-effects Model 1	Fixed-effects Model 2	Fixed-effects Model 3	Fixed-effects Model 4
Initial level of income	-0.0169* (-1.70)	-0.0371*** (-3.41)	-0.0365** (-2.46)	-0.0365** (-2.30)
Population	-0.8314*** (-3.91)	-0.5626*** (-2.77)	-0.7213*** (-3.18)	-0.7213*** (-3.17)
Investment	0.05551* (1.97)	0.0515* (1.98)	0.0585** (2.16)	0.05683** (2.14)
Education	-	0.0531*** (4.43)	0.0585*** (4.60)	0.0585*** (4.05)
Public expenditures	-	-	-0.0505* (-1.78)	-0.0504* (-1.74)
Infrastructures	-	-	-	-0.0002 (-0.01)
Intercept	-1.8584*** (-3.78)	-0.5787 (-1.16)	-1.1115* (-1.90)	-1.1135* (-1.87)
Within R^2	0.4923	0.5423	0.5588	0.5591
Nb. of obs.	145	145	145	145

Source: Author's calculation, based on China Statistical Yearbook (1996-2010).
Notes: Robust standard errors into brackets. Level of statistical significance: 1 %***, 5 %**, and 10 %*. Time dummies are not reported.

Table A4. Determinants of the Growth Rate of Regional per Capita GDP in China (1995-2009) using System GMM Estimator: Robustness Check with Annual Data

Variables	SYS-GMM Model 1	SYS-GMM Model 2	SYS-GMM Model 3	SYS-GMM Model 4
GDP_{t-1}	0.1840***	0.1481***	0.1324*	0.0764
	(3.05)	(3.15)	(1.85)	(1.11)
Initial level of income	-0.0403*	-0.0487***	-0.1451**	-0.0163
	(-1.78)	(-2.64)	(-2.10)	(-0.09)
Population	-0.8958	-0.6317	-0.6596	-0.9872
	(-1.03)	(-1.42)	(-1.06)	(-1.11)
Investment	0.0995*	0.0543	0.0194	0.0629
	(1.98)	(1.47)	(0.32)	(0.80)
Education	-	0.0249*	0.0840*	0.0403
		(2.00)	(1.82)	(0.52)
Public expenditures	-	-	-0.1923*	-0.1799
			(-1.70)	(-1.51)
Infrastructures	-	-	-	0.0872
				(1.26)
Intercept	1.8515	-0.9132	-0.3699	-1.3525
	(1.03)	(-0.90)	(-0.25)	(-0.50)
Nb of observations	406	406	406	406
Nb of individuals	29	29	29	29
Nb of instruments	8	10	12	14
Hansen test of	1.51	2.54	13.82	12.03
overidentifying restrictions	(0.680)	(0.638)	(0.017)	(0.061)
Arellano-Bond test for AR(1)	-3.74	-3.68	-3.46	-3.48
	(0.000)	(0.000)	(0.001)	(0.001)
Arellano-Bond test for AR(2)	1.25	1.38	1.11	0.45
	(0.211)	(0.167)	(0.268)	(0.649)

Source: Author’s calculation, based on China Statistical Yearbook (1996-2010).

Notes: Annual data for 29 provinces from 1995 to 2009; Two-step system GMM estimations with Windmeijer’s (2005) finite-sample correction for the variance-covariance matrix; Robust standard errors into brackets for GMM estimates, p-value into brackets for Hansen and Arellano-Bond tests. Level of statistical significance: 1 %***, 5 %**, et 10 %*. Time dummies are not reported.

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Received September 25, 2013, Revised April 22, 2014, Accepted September 11, 2014.