The Historical Process of Convergence

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Abstract

This paper tests the convergence of 53 countries vis-à-vis the United States using two different methods: unit root tests (ADF and KPSS) and a kalman filter test. The ADF test accepts convergence extremely rarely whereas the KPSS procedure accepts this hypothesis rather loosely. The Kalman filter procedure seems to be more germane to the usual definition of convergence. A clear evidence of convergence appears only for Japan after the second World War. Other cases seem fragile and rely only on a few exceptional points. Conditional convergence characterises some other developed countries, but a mere characterisation of 'catch-up' can only be applied to others.

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1. Introduction

The recent theoretical literature on economic growth has emphasized that one may derive different implications regarding the issue of convergence of income per capita according to the theoretical perspective chosen. Whereas the neo-classical growth model predicts that steady state GDP per capita should be the same across (structurally similar) countries, most endogenous growth models predict persistent differences in development levels. It is therefore important to test empirically the reality of convergence or divergence of countries with respect to the levels of GDP per capita or productivity. There now exists an abundant literature on convergence and divergence[1]. Most of the empirical literature has used a

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[1] For an assessment of the debate, see for instance the July 1996 issue of the *Economic Journal* and particularily Durlauf [1996]. See also Durlauf and Quah [1998].

framework derived from or compatible with the 'extended-Solow' model tested on cross-section data, even when the theoretical reference point is not neo-classical growth theory. For the latter, convergence is the pattern followed by a country toward its own steady state. When all countries have the same saving rates on physical and human capital and the same growth rate of the population, they should converge to the same steady state. Therefore, all countries should eventually reach the same level of income per capita. If on the other hand countries are structurally different, for instance if saving rates are different, they will have different levels of steady state GDP per capita. Anyhow, within the framework of neo-classical growth theory, one should observe a negative impact of the initial level of income on growth, whether convergence is unconditional - i.e. all countries converge to the same steady state - or conditional - when countries are structurally different -.

The results from empirical studies on cross-country data generally favour the conditional convergence hypothesis. A few papers have used panel data and came to similar conclusions. On the other hand, only a few studies have tested the convergence hypothesis with the help of time series. Bernard and Durlauf [1996] proposed a convergence test based on the stationarity of pair-wise differences in per capita GDP. Applications of this test to long time series leads to the rejection of the convergence hypothesis more often than with cross-section based tests. This is not surprising considering that this test is extremely demanding: it detects convergence for series which have reached or are near their asymptotic distributions. In other words, this test detects convergence once it has occurred. Hall et al. ([1992], [1993]) and St. Aubyn [1996] use a Kalman filter based test that seems more fit to check convergence in progress.

The aim of this paper is to compare the two time series based convergence tests using long term data taken from Maddison [1995] and to show that reaching a conclusion on the issue of convergence depends on the time-period considered as well as on the definition of convergence. The second section presents the two types of tests that will be used in the paper. Section 3 exposes the differences between these tests and Section 4 shows how to use them to test for actual convergence. Empirical results are presented in Section 5 and Section 6 broadens the testing framework in order to account for historical accidents.

2. Definition and tests

By convergence, economists generally mean that the level of development of two countries will eventually be the same. Operational definitions of convergence have been much debated. For our purpose in this paper — studying the evolution of relative output per capita in the long run — we retain the following definition already used by Hall, Robertson and Wickens [1993]. We consider y_i and y_j, the logarithm of output per capita for country i and, respectively j, and will say there

is convergence between country i and j if

$$\lim_{t\to\infty} E\left(y_{it} - y_{jt} - \alpha\right) = 0 \tag{2.1}$$

$$\lim_{t\to\infty} \mathrm{Var}\left(y_{it} - y_{jt}\right) = \sigma^2 \tag{2.2}$$

We want that asymptotically, the expectation of the difference in the logarithm of output per capita tend toward a fixed level α. For these two countries to eventually attain the same level of development, α must be null. On the other hand, α different from zero would mean there would always be a differential of development explained exogenously, an idea sometimes referred to as conditional convergence.

To require that the variance of the difference in output per capita σ^2 should vanish asymptotically is undoubtedly too strong. It is more realistic to require that variance be bounded to account for intrinsic variability in the output of each country.

If y_{it} and y_{jt} are cointegrated in such a manner that $y_t = y_{it} - y_{jt}$ is a stationary process, conditions (1) and (2) will of course be satisfied. But, as Hall, Robertson and Wickens rightly underline, cointegration is not a necessary condition: conditions (1) and (2) concern the asymptotic behaviour of the time series only, whereas cointegration must be verified at all time. This distinction is particularly important if structural change intervenes in the stochastic process determining output.

On the other hand, considering two countries where the difference in output per capita remains stationary as an evidence of convergence is somewhat stretching the usual meaning of the word. Nothing in the concept of stationarity suggests that the differences between the two countries will further diminish.

In the rest of the paper, we will compare two tests of the stationarity for the difference in output per capita with a third one which only checks the asymptotic condition.

2.1. Testing convergence

The usual test of stationarity is the Dickey-Fuller test which in fact tests the hypothesis of a unit–root:

$$y_t = \mu + \rho \cdot y_{t-1} + u_t \tag{2.3}$$

The null hypothesis is $\rho = 1$ and the alternative one $\rho < 1$. In this case, it is non–stationarity—non–convergence—which is the null hypothesis.

It may be desirable to test directly the null hypothesis of stationarity. Such a test has been proposed by Kwiatkowski, Phillips, Schmidt and Shin [1992] (KPSS). In the framework of a local trend/random walk model, they suggest to test whether the variance of the stochastic trend component is null:

$$y_t = \alpha_t + \varepsilon_t \tag{2.4}$$

$$\alpha_t = \alpha_{t-1} + u_t \tag{2.5}$$

The null hypothesis is here $\mathrm{Var}(u_t) = 0$.

The third test, proposed by Hall, Robertson and Wickens (1992, 1993) (HRW) uses a variation of the local trend/random walk model: the damped trend model.

$$\begin{aligned} y_t &= \alpha_t + \varepsilon_t && (2.6)\\ \alpha_t &= \alpha_{t-1} + u_t && (2.7)\\ \mathrm{Var}(u_t) &= \xi \cdot \mathrm{Var}(u_{t-1}) && (2.8) \end{aligned}$$

In this case, when ξ is smaller than one, the variance of the stochastic trend vanishes asymptotically. It is the stationary noise ε_t which accounts for the variance remaining asymptotically between the two series. The null hypothesis is $\xi = 1$ against $\xi < 1$. Again this is a test of the null hypothesis of non–convergence.

2.2. Comparison between the three tests

Under their respective null hypothesis, the three tests can be compared in the framework of the following ARIMA model:

$$y_t = \mu + \rho \cdot y_{t-1} + u_t + \theta \cdot u_{t-1} \qquad (2.9)$$

The Dickey-Fuller test consists in testing $\rho = 1$ under the maintained hypothesis $\theta = 0$.

For the KPSS test, it can be shown (Harvey [1989] p.68) that the local trend model is a restricted version of an ARIMA(0,1,1). In the local trend model the autocorrelation function of Δy_t has one spike as would a MA(1) process. The correspondence is:

$$\begin{aligned} \theta &= -0.5 \cdot \left\{ \left[\lambda^2 + 4 \cdot \lambda \right]^{1/2} + \lambda + 2 \right\} && (2.10)\\ \lambda &= \mathrm{Var}(u_t)/\mathrm{Var}(\varepsilon_t) && (2.11) \end{aligned}$$

In this context, λ is the signal to noise ratio. The KPSS test consists in testing $\theta = -1$ under the maintained hypothesis $\rho = 1$.

The setup is similar for the HRW test, only in this case we test whether θ tends toward -1 as $\mathrm{Var}(\varepsilon_t)$ vanishes (in fact the null hypothesis is whether $\mathrm{Var}(\varepsilon_t)$ does not vanish).

2.3. Implementation of the tests

For the implementation of these tests in practice, additional problems must be addressed. The main one has to do with possible autocorrelation in the stationary noise of the model.

2.3.1. The Dickey–Fuller test

We use therefore the Augmented Dickey–Fuller (ADF) test to test the unit–root hypothesis:

$$\Delta y_t = \mu + \delta \cdot t + \phi \cdot y_{t-1} + \sum_{i=1}^{l} \gamma_i \cdot \Delta y_{t-i} + e_t \tag{2.12}$$

The number of lags l is determined through the method advocated by Perron [1994]: starting with a large number of lags, we successively eliminate from the end non-significant lags.[2] Results are reported in Table 1 to 3. The methodology used here follows Holden and Perman [1994]. The statistic Φ_3 is used to test the joined hypothesis $\phi = 0$ and $\delta = 0$[3]. If we accept the null hypothesis of a unit–root, this conclusion is double-checked by examining t_ϕ using the non–standard distribution tabulated by Fuller [1976] (Table 8.5.2). Having concluded to non–convergence, we stop the procedure here.

If we reject the joined hypothesis $\phi = 0$ and $\delta = 0$, we check that $\delta = 0$ using a standard t-distribution. The statistic is reported in column t_δ. If we reject this last hypothesis, we conclude again to non–convergence. Otherwise, we double–check $\phi = 0$ using a standard normal distribution[4]. Only then can one conclude to convergence.

2.3.2. The KPSS test

Kwiatkowski et al. [1992] propose to test the hypothesis of stationarity through the LM statistic, $\hat{\eta}_\mu$, formed as follows:

$$e_t = y_t - \bar{y} \tag{2.13}$$

$$S_t = \sum_{i=1}^{t} e_t \quad t = 1, 2, \ldots, T. \tag{2.14}$$

$$\hat{\eta}_\mu = T^{-2} \cdot \sum_{t=1}^{T} S_t^2 / s^2(l) \tag{2.15}$$

$$s^2(l) = T^{-1} \cdot \sum_{t=1}^{T} e_t^2 + 2 \cdot T^{-1} \cdot \sum_{s=1}^{l} w(s,l) \cdot \sum_{t=s+1}^{T} e_t \cdot e_{t-s} \tag{2.16}$$

$$w(s,l) = 1 - s/(l+1) \tag{2.17}$$

$s^2(l)$ is a consistent estimator for $\sigma^2 = \lim_{T\to\infty} T^{-1} \cdot E\left(S_T^2\right)$ when the ε_t in the original model satisfy the linear process conditions of Phillips and Solo [1989], which allow for all ARMA processes with either homogeneous or heterogeneous

[2] For the entire sample, we used a maximum number of lags of 20 and of 10 for the half–samples before and after World War II.

[3] The critical values for the test come from Fuller [1976] and Dickey and Fuller [1981].

[4] See Holden and Perman [1994] for the justification of using a normal distribution in this case.

innovations. $w(s,l)$ is the Barlett spectral window. In this test, it is difficult to estimate the size of the window, l, empirically. In all our tests, l is set to 8.

In Tables A4 to A6, we report the results for $\hat{\eta}_\mu$. The critical values for this statistic is tabulated in Kwiatkowski et al. (1992).

2.3.3. The Kalman filter test

The Kalman filter test proposed by Hall et al. ([1992], [1993]) and St. Aubyn [1996] is based on the following:

$$\begin{aligned} y_t &= \alpha_t + \varepsilon_t \\ \alpha_t &= \alpha_{t-1} + \mu_t \\ \varepsilon_t &\sim N\left(0, \sigma^2\right) \\ \mu_t &\sim N\left(0, \Omega_t\right) \\ \Omega_t &= \xi \cdot \Omega_{t-1} \end{aligned}$$

with Ω_0 given. The model above is written in state-space form and the likelihood function can be constructed with the Kalman filter, giving ML estimates of the parameters. A test of no convergence is defined by H_0: $\xi = 1$ against H_a: $\xi < 1$. The statistic of interest is defined as:

$$T\left(\xi_{ML}\right) = \frac{\xi_{ML} - 1}{\sqrt{\left(h^{-1}\right)_\xi}}$$

where $\left(h^{-1}\right)_\xi$ is the diagonal element of the Hessian matrix corresponding to ξ. The distribution of this statistic was tabulated by St. Aubyn [1996]. In Tables A7 to A9, we report $\hat{\xi}$. If it is larger than one, we accept immediately the null hypothesis of no–convergence. Otherwise, we examine the statistic t_ξ. In addition, we report $\hat{a}_T$, the estimated value of the stochastic trend at the end of the sample. This is the value of the remaining differential between the two countries as computed by the model.

3. Testing for possible economic convergence

The three tests presented above are really only tests of conditional convergence only: for the ADF and KPSS tests, it is enough that the difference in output be stationary around a constant. For the Kalman filter test, it is enough that the process tends toward a variable stationary around a constant. To distinguish between conditional convergence and strict convergence, it is necessary to further test whether this constant is null.

For the ADF and KPSS tests, once the stationarity of the process is established, testing whether the constant is null does not present any difficulty. Under

the maintained hypothesis of stationarity, the estimator of the intercept is distributed as a Student-t. In the tables, once stationarity has been accepted for the ADF test or the KPSS test, we report the t_μ statistic which corresponds to the estimation of an ADF regression without linear trend.

In the approach of Hall et al., the test criterium is whether the parameter ξ is smaller than one. Asymptotically, the variance of μ_t will be zero, α_t will become constant, but nothing warrants that α_t itself be zero, which would be required to obtain the same level of development in the two countries.

On the other hand, at the end of the estimation period, noted T, the variance of μ_T, Ω_T may still be different from zero and it is still possible that α_t wanders in the future away from its value at the end of the estimation period. After all, it is a unit root process.

Using the assumption that the variance of μ_t will ultimately die off, we propose to compute a confidence interval for the asymptotic value of α_∞ around its value, α_T, at the end of the estimation period. The variance of α_∞, given α_T, is as follows:

$$\begin{aligned}
\alpha_\infty &= \alpha_T + \sum_{i=T+1}^{\infty} \mu_i \\
\mathrm{var}(\alpha_\infty|\alpha_T) &= \sum_{i=T+1}^{\infty} \mathrm{var}(\mu_i) \\
&= \sum_{i=1}^{\infty} \xi^i \cdot \Omega_T \\
&= \frac{\xi \cdot \Omega_T}{1-\xi}
\end{aligned}$$

In the model, α_∞ follows a normal distribution, but in practice, ξ, Ω_T and α_T are estimated. The confidence intervals that we report and that are based on the normal distribution are therefore probably too small: we will reject the null hypothesis too often. If zero does not belong to these confidence interval, it is most unlikely the two countries will ever reach the same level of development if they keep following the same process.

4. Testing historical convergence

In order to compare the empirical features of these three tests of convergency, we applied them to the difference in GDP per capita between the US and 53 countries, including developed as well as Third World countries. The choice of the US as the refence country is influenced by two reasons: (i) the US is the leader country on the most part of the period under study so that it constitutes the most obvious refence point and (ii) even for the period where the US level of per capita GDP lags behind richer countries, the US is the most dynamic country in the sense that there is no prolonged period where the gap between the US and

the richest country widens or even stays constant apart from the episode of the 1930s crisis. Between 1870 and the beginning of the 20th century, the US caught up to the richest countries and eventually overtook them.

GDP per capita is different from labour productivity. Rates of activity differ across countries as well as the number of working hours. If for instance the level of GDP per capita in France was 83% of the US level in 1992, the level of GDP/hours for the same country was 103% of the US level. On the other hand, figures for Japan are respectively 90% and 69%. This reversal in the hierarchy of countries comes from differences in the number of working hours per year: 1542 hours in France versus 1876 hours in Japan, i.e. a difference of 22%. Therefore some countries have experienced a more 'extensive' growth pattern than others; the level of working hours has been kept to a higher level in Asia (2800 hours in Korea, 2500 in Taiwan) than in Europe (ca. 1500-1600 hours) or Latin America (ca. 1800-2000 hours). However, yearly data for labour productivity are not available, so that the indicator of wealth, GDP per capita, will be used instead. Incidentally, most of the empirical studies on convergence have stuck with GDP per capita rather than an indicator of productivity.

Data are provided by Maddison [1995] and are available from 1870 to 1994, except as indicated[5]. When enough data were available, we applied the three tests to three different periods: the entire sample, before World War II (1870–1938) and after World War II (1950–1994).

When testing for convergence on the entire period, we must have in mind that it is the Industrial Revolution or even earlier developments which created most of the differences in output per capita[6] and we test whether economic growth from the end of the 19th Century until now brought about equalization in the level of development.

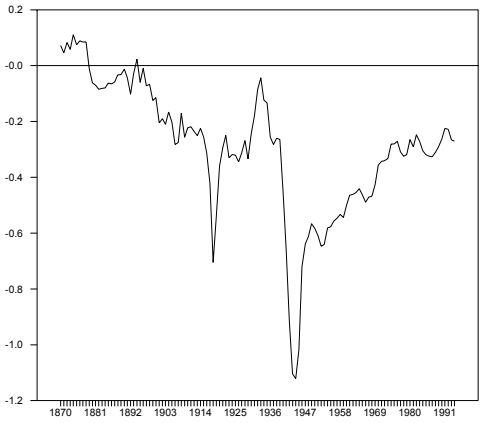
A cursory knowledge of economic history or a quick glance at the graphs showing the evolutions of GDP per capita in various countries show us that things are more complex: as mentioned before, the output per capita of the US only caught up with the wealthiest nations at the turn of the Century: Australia, New Zealand, United Kingdom, Belgium or the Netherlands. The Great Depression

[5] The samples are the following: Ireland 1947–1994; Greece 1929–1994; Portugal 1947–1994; Spain 1900–1994; Switzerland 1899–1994; Japan 1885–1994; Korea 1911–1992; Turkey 1923-1994; Bulgaria 1950-1992; Czekoslovakia 1948-1992; Hungary 1946-1992; Poland 1950-1992; Romania 1960-1992; USSR 1946-1992; Yugoslavia 1947-1992; Argentina 1900-1994; Brazil 1900-1994; Chile 1900-1994; Columbia 1925-1994; Mexico 1921-1994; Peru 1913-1994; Venezuala 1900-1994; Bangladesh 1948-1992; Burma 1950-1992; China 1950-1992; India 1900-1992; Indonesia 1900-1992; Pakistan 1948-1992; Philippines 1950-1992; Taiwan 1903-1992; Ivory Coast 1950-1992; Egypt, Ethiopia, Ghana, Kenya, Morocco, Nigeria, South Africa and Tanzania 1950-1992.

[6] The period between 1820 and 1870 brought about some divergence in the levels of GDP per capita for some developed countries. Let us take for instance 15 OECD countries: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, UK and the US. The ratio of the standard deviation to the mean increased from 0.21 in 1820 to 0.39 in 1870. For comparison, this indicator had decreased to 0.12 in 1994.

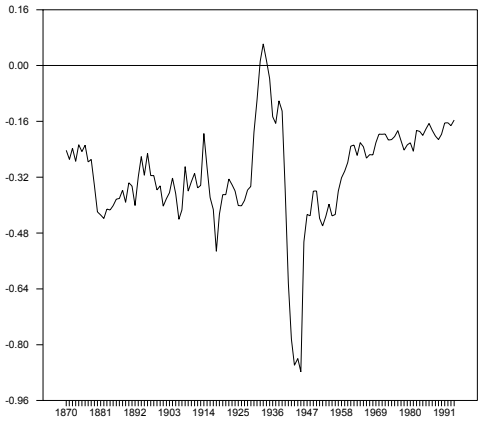
was a large negative shock on the US GDP per capita level. It affected to a large extent other countries too (Germany for instance), but others experienced virtually nothing. Then, World War II saw a dramatic increase in the difference between the US and the other nations. This difference is less pronounced for the neutral nations of World War II: Sweden and Switzerland, and most severe for the nations which were defeated: Germany and Japan. In any case, there are specific episodes of catching–up which occurred after World War II and it is interesting to see how the three tests performs on this specific period.

GDP Difference UK-USA



GDP Difference Belgium-USA

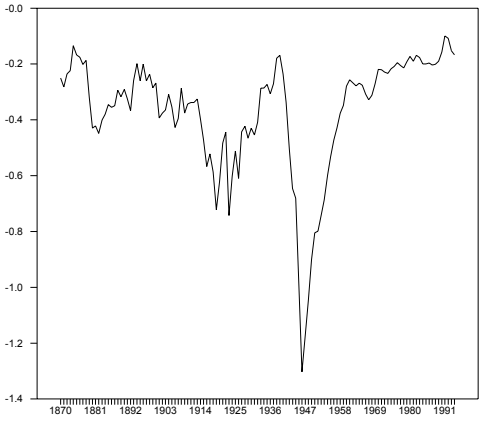
Not surprisingly the ADF test almost never accepts the hypothesis of convergence on any of the three periods: the exceptions are Denmark between 1870 and 1994 and Germany between 1950 and 1994, where the ADF test reports cases of conditional convergence. There is a doubt for Australia after WWII, because a contradiction appears between the conclusions from the Φ_3 and t_ϕ tests: the former rejects the absence of a unit root while the latter accepts it. The tests also accept conditional convergence for Mexico between 1921 and 1994, but reject any pattern of convergence for the post war period. More surprising is the case of Ethiopia, where the doubt regarding the conclusion of the ADF test finds no support in the figures (see Graph). A simple look at the compared evolutions of the GDP per capita levels in the US and Ethiopia would rather lend support to the conclusion of divergence. As the graph below shows, the gap has kept widening from the late 1950s onwards. To sum up, the ADF test can be trusted for convergence between two countries which stay near to each other for a long period.



GDP Difference Denmark-USA

GDP Difference Australia-USA

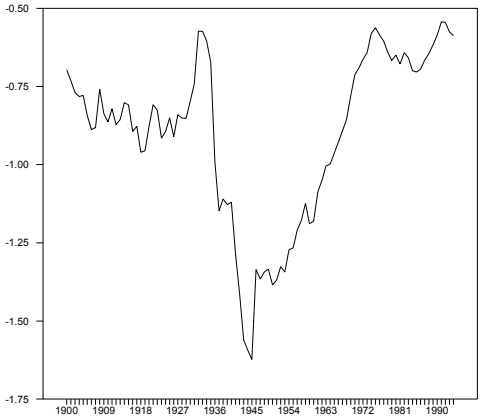
GDP Difference Ethiopia-USA



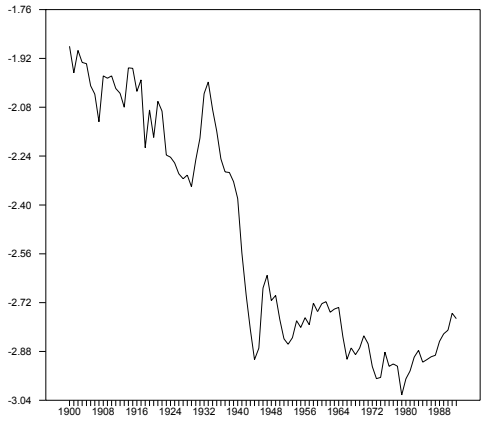
GDP Difference Germany-USA

The KPSS test accepts convergence or conditional convergence much more often than the ADF test. Furthermore, this test accepts not only conditional convergence for a large number of countries, but also strict convergence for countries which stay quite afar from the level of output per capita of the US: Spain between 1900 and 1994, Colombia between 1925 and 1994 or Taiwan between 1903 and 1992. The graphs clearly show that the conclusion of unconditional convergence for most of the countries where the KPSS test indicates so is preposterous. The explanation for such a finding lies in the estimation. Despite a large number of lags in the ADF test (17 for Spain), the adjustment of the ARMA model is quite poor and it becomes difficult to reject the hypothesis that the intercept is null. If results concerning unconditional convergence seem unacceptable, those regarding conditional convergence look more reasonable. The conclusion of conditional convergence is acceptable for countries whose growth pattern seems parallel to that of the US: Denmark, France, Germany or Italy before World War II for instance. On the other hand, this test leads to reject convergence for most

European countries after the second World War: Austria, Belgium, France, Germany, Italy..., i.e. the countries usually held to belong to the OECD convergence club[7].More surprising yet, the KPSS test accepts unconditional convergence for India and Indonesia over the same sub-period.

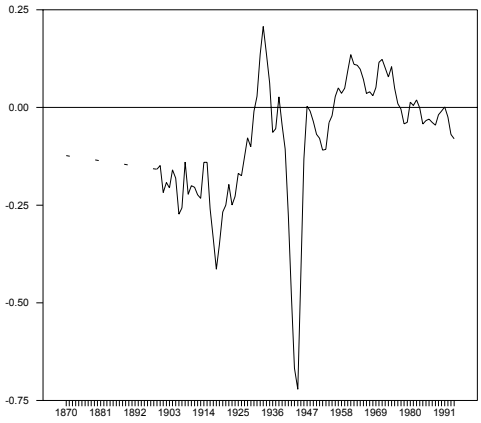


GDP Difference Spain-USA

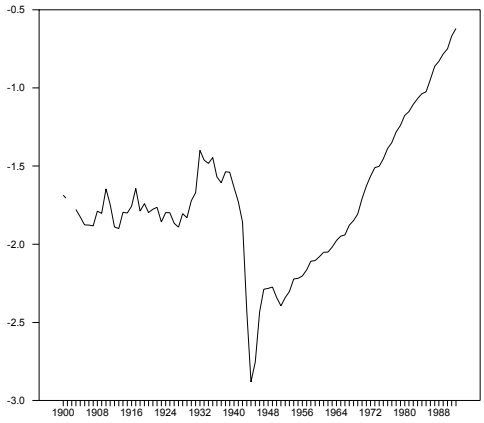


GDP Difference India-USA

The Kalman filter test accepts convergence on the entire period only in the case of Switzerland and Taiwan, but it refuses convergence for these two countries when the sample is split into sub–periods. Convergence, either conditional or unconditional, is always rejected for the pre WWII period. For the post-World War II period, the test reports conditional convergence for Greece, Italy, the Netherlands, Austria, Yugoslavia, Canada, Egypt, Kenya, Australia and New Zealand. It reports unconditional convergence for Japan and Germany.



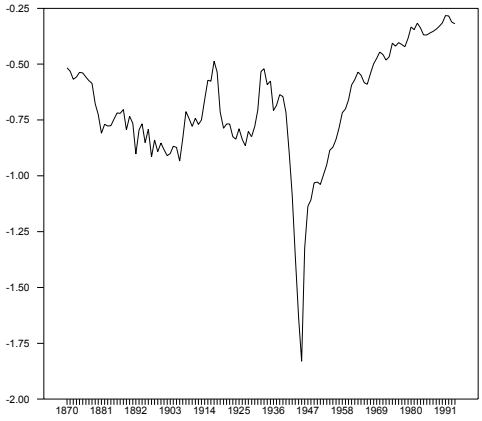
GDP Difference Switzerland-USA



GDP Difference Taiwan-USA

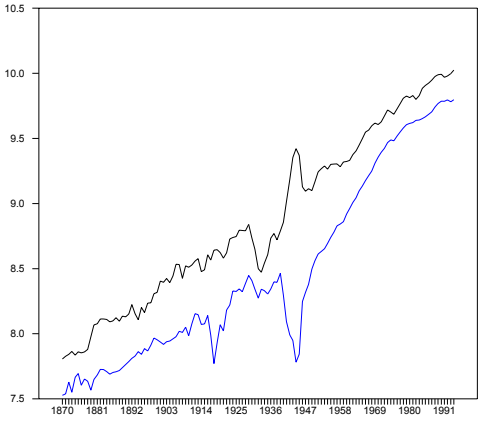
[7]See for instance Durlauf and Johnson [1995].

GDP Difference Greece-USA

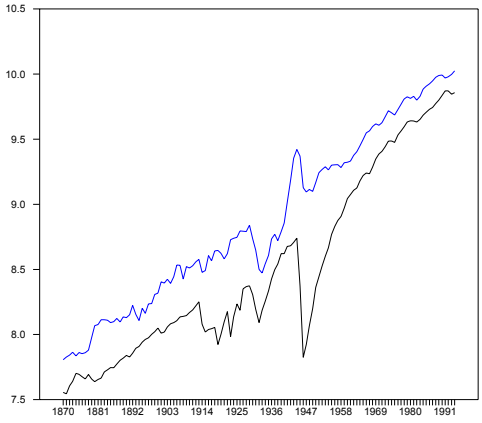


GDP Difference Italy-USA

From the simple examination of the graphs, it is not always possible to predict the result of the Kalman test. For example, France and Germany display very similar features, and one suspects that it is probably the lower starting point in 1950 alone which can explain that the Kalman filter test reports convergence for Germany and the US but not for France.

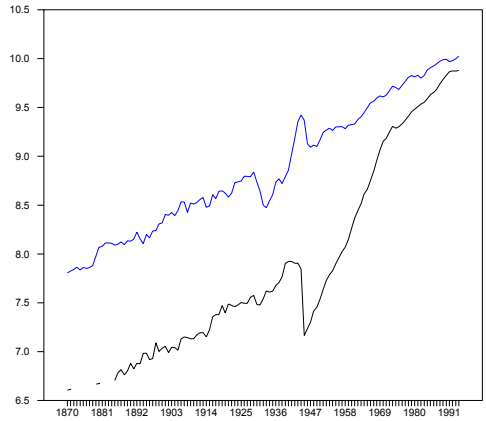


France and the US



Germany and the US

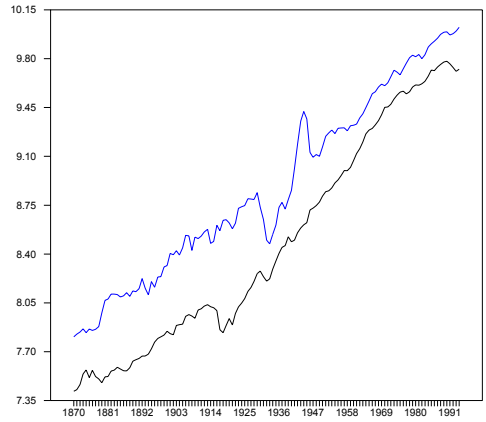
Table 1 sums up the results of the convergence tests. The only clear case of unconditional convergence is Japan after 1950. The other results are fragile, either based on unit root tests with a large error in the estimation or, when based on the HWR test, non reproducible on subperiods for the Swiss case or sensitive to the estimation period for the German case. For some developed countries, the pattern of growth can at best be described as a catch-up to the US level of per capita GDP, i.e. a reduction in the gap without any clear pattern of convergence. Some countries seem to converge conditionally, staying at a large distance from the US, for instance Greece.



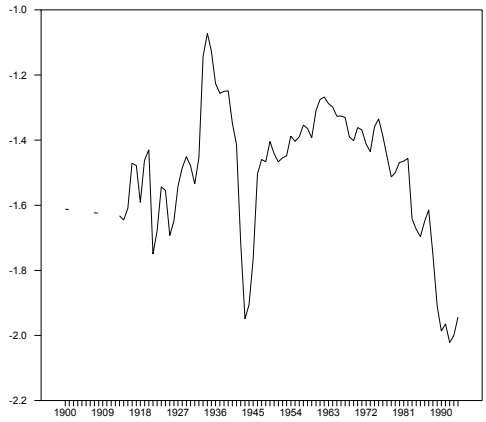
Japan and the US

TABLE 1

Sweden and Switzerland are two countries where conclusions are difficult to draw. Swiss output per capita has stayed very near to that of the US over the whole period. All eastern countries have experienced a major shock in the latter part of the 1980s which make the conclusions rather fragile. For instance, the conclusion of conditional convergence is based on the results of the KPSS test. The HRW test cannot detect conditional convergence because the variance suddenly increases towards the end of the period. The same is true to some extent for Peru, where the relative decline since the early 1970s blurs the result of conditional convergence.



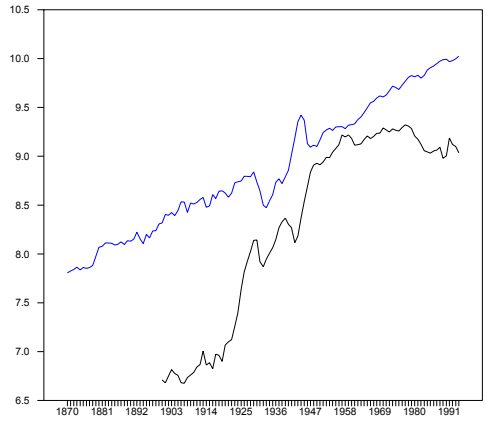
Sweden and the US



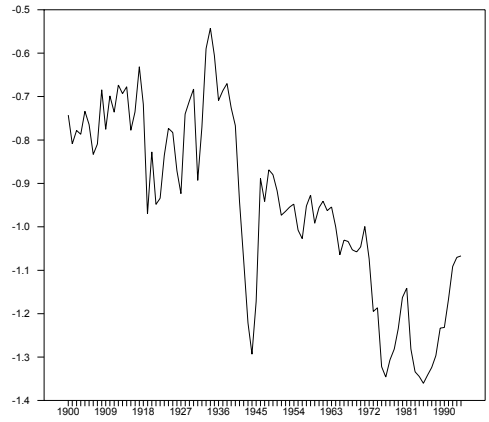
DP Difference Perou-USA

It is not possible to give a conclusion for a certain number of countries. Venezuela is a special case of a country catching up to the US until the late 1950s and experiencing a relative decline afterwards. China is catching up since the late 1970s, after a period of evolution parallel to the US. The HRW test

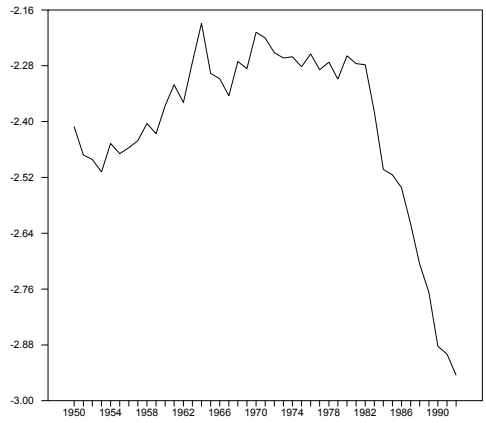
would conclude to conditional convergence since 1900 for India, but the result does not carry over to any of the sub-periods. The conditional convergence result for South Africa given by the KPSS test appears dubious considering the sharp decline experienced by this country after 1980. Likewise, the same phenomenon applies to Tanzania, Morocco or Ivory Coast.



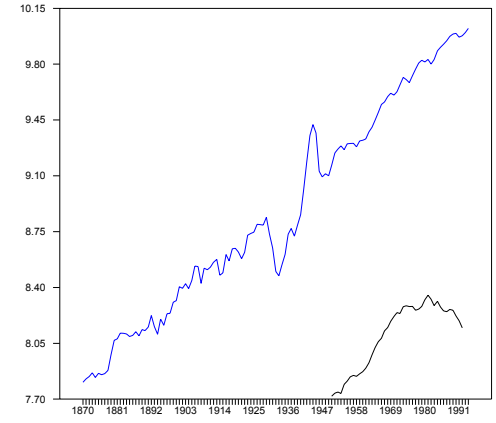
Venezuela and the US



DP Difference China-USA



GDP Difference Ivory Coast-USA



South Africa and the US

5. Where does divergence come from? or the importance of catastrophic events

The testing period conveys a certain conception of convergence. When we perform the tests on the period 1870-1994, the implicit hypothesis is that the industrial revolution was a big bang and convergence took up from there. However, catastrophic events such as the Great Depression or World War II dramatically increased the difference in output per capita between the US. and most of the other nations.

In the Kalman filter test, the appearance of obvious outliers in the middle of the sample leads necessarily to the rejection of the hypothesis of a decrease in the variance of the stochastic trend. If, on the other hand, we consider these outlier points as the result of exogenous shocks, does one obtain the same results on the test? To study this proposition, we introduced a dummy in the model for US. and Japan for 1945, then 1945 and 1946, with the following results:

TABLE 2

As the above results indicate, it seems to be enough to neutralize the observations for 1945 and 1946 by dummies to obtain a result of convergency between Japan and the US. in the 20th century.

In opposite manner; the result of convergence between Germany and the US. after World War II depends entirely on the reconstruction years at the beginning of the 1950s.

TABLE 3

As we eliminate from the sample the most extreme points, the estimate of ξ increases and becomes less precise. For samples starting after 1953, it becomes impossible to reject the hypothesis of no convergency. Note that when the test accepts convergency; the statistic is very near the critical value. This result confirms the finding of Hall and St. Aubyn [1995] about the sensitivity of the Kalman filter test to the magnitude of the difference in per capita output at the beginning of the sample. It should be underlined that in the case of Germany, it is really the exceptional circumstances of the reconstruction years which lead to the conclusion of convergence in the post-war period.

6. Conclusion

This paper has tested for convergence of 53 countries vis-à-vis the United States using three different tests, without explicit reference to a specific theory of economic growth. It appears that clear evidence of unconditional convergence appears only in the case of Japan after the second World War. Other cases seem fragile and rely only on a few exceptional points. There are cases of conditional convergence, and some countries stay quite far from the US level of GDP per capita. The growth after WWII appears to be different from before the war for a large number of countries.

As expected, the ADF procedure, which tests the null hypothesis of no convergence, accepts convergence extremely rarely when the KPSS procedure, which tests the null hypothesis of convergence, accepts this hypothesis rather loosely. This points once more to the difficulty of testing for stationarity on economic data. It also underlines the peculiar definition of convergence which underlies these tests: convergence must have already occurred. However, results of conditional convergence given by the KPSS tests seem to make sense in most cases.

The Kalman filter procedure seems to be more germane to the usual definition of convergence. It is however to be noted that when the difference in per capita output decreases without a diminishing variance of the stochastic trend, the test generally concludes to the absence of convergence.

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