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L'essor et le déclin de l'Occident: une perspective géographique (The Rise and Fall of the West: a Geographical Perspective)

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The Rise and Fall of the West: a Geographical Perspective*

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Abstract

This paper proposes a new representation of the worldwide distribution of human population and economic activity over two millennia. Combining the Maddison and the G-Econ databases, it tracks the evolution of the world's demographic and economic centers of gravity during the 1-2010 period. The distributional and temporal patterns that emerge are clear and contrasted, with a stable East-Asian predominance during the first eighteen centuries, followed by a boomerang-like westward shift during the last two centuries. New turning points are identified, suggesting that the reversal of the Western shift occurred as early as the 1920s in demographic terms and in the 1950s in economic ones.

JEL classification: N10, O10 and R10

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1. Introduction

The end of the Cold War and the pursuit of globalization have been associated with radical changes in the distribution of power and wealth across countries. This has led to a frenzy of recent studies characterizing the new world in terms of both economics (e.g. offshoring and unbundling as in Blinder (2006) and Baldwin (2011)) and politics (e.g. power, governance and multipolarity as in Cox (2011), Saxer (2009) and Young (2010)). Although most of these studies are unanimous in considering that the politico-economic pendulum has been swinging back to Asia in recent decades, several questions remain regarding this rebalancing process at the global level: when did it start? what happened before? how to measure those trends in the most synthetic way?

The answers provided in this paper are based on a simple and new representation of global trends. We rely on the world's economic (or demographic) center of gravity (WECG or WDCG), which encapsulates into a single point the distribution of either GDP or population on the globe. Projecting this center of gravity on the earth's surface year after year leads to a simple trajectory which characterizes the evolution of the distribution of economic activity (or human populations) at the worldwide level. Recent attempts to estimate the WECG have led to the same conclusion: it is presently shifting East at an accelerated pace (Grether and Mathys (2010, 2011), Quah (2011)). However, as the available evidence is based on the last decades only, a longer-run perspective is still missing.

This paper relies on the longest time period available today, i.e. the Maddison database, which provides data on world GDP and population over the last two millennia (Maddison (2010)). We also provide new indicators to estimate the share of the overall change which is due to changes between rather than within continents, and to assess the contribution of each continent to the overall process. The analysis provides new insights on the timing and magnitude of the changes affecting the spatial distribution of human population and economic activity. Even though Comin et al (2010) have found strong technological persistence in history, our results suggest large swings and important trend-breaks in the world-wide demographic and economic balance since 1820. Critical reversals are identified, which only become apparent when the geographical dimension is duly taken into account.

Section 2 presents how world centers of gravity are measured and explains how their changes can be decomposed into the between and within-continent effects. Section 3 discusses in depth the database. Section 4 outlines the main results and proposes an interpretation of the trends and turning points along three major subperiods. Section 5 concludes.

2. Methodology

The presentation below is limited to the concepts used in the present paper. For a more complete exposition, see Grether and Mathys (2011).

2.1 World centers of gravity

Imagine that the Earth is covered by a regular lattice of n grid cells. For each cell we have data on two socio-economic variables v: human population (H) and economic activity (Y). The Cartesian coordinates of the center point of cell i are denoted by (x_i, y_i, z_i), and the share of cell i in the world total of variable v by s_v^i (v=H,Y). The Cartesian coordinates of the world's demographic (WDCG) or economic (WECG) center of gravity are defined by the weighted average of the cells' Cartesian coordinates :

$$x_v = \sum_{i=1}^{n} s_v^i x_i \;,\; y_v = \sum_{i=1}^{n} s_v^i y_i \text{ and } z_v = \sum_{i=1}^{n} s_v^i z_i \qquad (1)$$

The most critical dimensions of a gravity vector in spherical statistics are its orientation and its length (see e.g. Mardia and Jupp (2000)). To represent the orientation of the gravity vector, we follow here the usual convention of orthogonal projection upon the sphere's surface.[1] The resulting center will necessarily locate in between the main (demographic or economic) poles, as it is for the center of gravity of a barbell. Thus, the reader should not be surprised to see the projection of the WECG or WDCG, in terms of latitude and longitude, coincide with a seemingly unimportant spot regarding either population or human activity.

[1] See Quah (2011) for an alternative projection on a cylinder wrapping the Earth along the equator. An unconvenient property of this alternative convention is that the reported latitude of the projection of a given vector depends on its length. A particularly awkward consequence for the present study would be that the European center of gravity during the XXth century would appear at a larger latitude than the world center of gravity, even if the latter is closer to the polar axis, because the former is more than 50% larger. That is why we use the conventional orthogonal projection and we report orientation and length separately.

The length of the gravity vector is a crude indicator of the concentration of variable *v* on the sphere's surface. At the limit of maximum concentration, the length is equal to the sphere's radius, in our case 6371 km. In general, lower lengths indicate lower concentrations, but the relationship is not systematically true because of potential spatial compensations between subpopulations (e.g. a concentration of population in two antipodal cities would lead to a zero-length WDCG).

Finally, to capture the change over time of the gravity vector, this paper proposes a third « speed » indicator, which is simply the average distance per year covered by the tip of the gravity vector within the earth.[2]

2.2 Continental centers of gravity

Assume we can group cells by geographical categories, say continents, and let n_c denote the total number of cells included in category *c* ($n = \sum_{c=1}^{4} n_c$). By following the same logic as equation (1), the coordinates of any continental center of gravity are given by:

$$x_v^c = \sum_{i=1}^{n_c} s_v^{ic} x_i \,,\ \ y_v^c = \sum_{i=1}^{n_c} s_v^{ic} y_i \ \text{ and } \ z_v^c = \sum_{i=1}^{n_c} s_v^{ic} z_i \qquad (2)$$

where s_v^{ic} represents the share of cell *i* in the continental total of variable *v* (*v*=*H*,*Y*).

By combining equations (1) and (2), it is straightforward to show that:

$$x_v = \sum_{c=1}^{4} s_v^c x_v^c \,,\ \ y_v = \sum_{c=1}^{4} s_v^c y_v^c \ \text{ and } \ z_v = \sum_{c=1}^{4} s_v^c z_v^c \qquad (3)$$

where s_v^c represents the share of continent *c* in the world total of variable *v*.

[2] This is different from the distance covered by the projection of the gravity vector upon the earth's surface, which does not capture all the forces affecting the precise location of the gravity center.

Equation (3) shows that the world center of gravity can be obtained as a weighted average of the continental centers of gravity, i.e. it depends on both the continental shares and the position of the continental centers.

2.3 Between-continent and within-continent variations

Let us introduce a time subscript *t*, which may represent either a year or a decade, and denote by Δx_{vt} the temporal change of x_{vt}, i.e. $\Delta x_{vt} \equiv x_{vt} - x_{vt-1}$ (and similarly for Δs_{vt}^c, Δx_{vt}^c). Let us also denote by $\bar{x}_{vt}^c$, $\bar{s}_{vt}^c$ the average values of x_{vt}^c , s_{vt}^c over two consecutive periods, i.e. $\bar{x}_{vt}^c \equiv (x_{vt}^c + x_{vt-1}^c)/2$, $\bar{s}_{vt}^c \equiv (s_{vt}^c + s_{vt-1}^c)/2$. Finally, to simplify presentation, let us limit algebraic expressions to the case of Δx_{vt} (the extension to Δy_{vt} and Δz_{vt} is straightforward). Starting from equation (3), and following the additive decomposition procedure proposed by Dietzenbacher and Los (1999), which has the advantage of being path-independent, it is easy to show that:

$$\Delta x_{vt} = \sum_{c=1}^{4} \Delta s_{vt}^c \bar{x}_{vt}^c + \sum_{c=1}^{4} \bar{s}_{vt}^c \Delta x_{vt}^c , \tag{4}$$

The first right-hand side element of equation (4) captures variations *between* continents, the second one captures variations *within* continents. By dividing equation (4) by Δx_{vt}, and then aggregating over years and dimensions (*x*,*y*,*z*), we get a measure of the share of the locational variation of the world gravity center which is due either to between-continent or to within-continent variation. To avoid undesired compensations across years or dimensions, we adopt an aggregation procedure in which absolute values of changes are used to define the weights (see Appendix B for details.)

2.4 Contribution of each continent: an intuitive interpretation rule

How can we measure the contribution of each continent to the change in location of the world center of gravity? One possibility would be to use equation (4) to infer the share of continent *c* in the overall change of each coordinate of the gravity center. The problem with that option is that shares in Cartesian coordinates are not particularly telling in terms of orientation on the globe.

For that reason, we opted for a geographical representation in which we calculate the change in latitude and longitude generated by the change in a specific continental share (Δs_{vt}^{c}) and/or location (Δx_{vt}^{c}). This is not totally straightforward either, because Polar coordinates are non-linear functions of Cartesian coordinates.[3] As a result, the impact of a given change in a specific continental share and/or location depends on its rank in the sequence of the eight changes that are considered in equation (4) (four continents times two effects). As this rank is arbitrary, we considered all the possibilities and take the simple average between them in terms of changes in latitude and longitude of the world gravity center.[4]

Detailed results will not be reported due to space constraints (see figures A5,A6 in the Appendix for the 1820-2010 subperiod). However, they are consistent with a simple and *intuitive rule* which will be very useful in our interpretations (see section 4.3). For the between effect, this intuitive rule states that, if the continental share increases, and if the continental center of gravity locates East (North) of the world center of gravity, then the contribution of that continent to the longitude (latitude) of the world center of gravity will be positive (and vice-versa). For the within effect, the contribution of the continent to the longitude (latitude) of the world center of gravity will be positive if the continental center of gravity shifts East (North) (and vice-versa). Although this intuitive rule, which also applies to changes in concentration (length of vector), works most of the time, it is not systematically valid, in particular for latitude. This is due to compensations occurring between far-distant locations (see Appendix C for a discussion of the counter-intuitive cases).

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[3] If z is the dimension along the polar axis, the y axis is orthogonal to the Greenwich Meridian plane, and c is the length of the world gravity vector ($c = \sqrt{x^2 + y^2 + z^2}$), than latitude is given by $(180/\pi)\cos^{-1}(z/c)$ while longitude is given by $(180/\pi)\tan^{-1}(y/x)$ for $x > 0$, $(180/\pi)(-\pi + \tan^{-1}(y/x))$ for $x < 0, y < 0$ and $(180/\pi)(\pi + \tan^{-1}(y/x))$ for $x < 0, y > 0$.

[4] We proceed in two steps: (i) whether the between or the within effect is considered first, for all continents, and (ii) all possible ordering of continental changes. This leads to 48 combinations, each of which has the same weight in the average calculations. For the net continental impact (between plus within effect), 24 combinations are considered.

3. Data

The Maddison (2010) database is unique in providing consistent GDP and population data for the last twenty centuries at the world wide level. Since its apparition in the nineties, it has been extensively used by scholars to analyze a variety of issues, from the origin of economic growth (Golar and Moav (2002)) to the inequality among world citizens (Bourguignon and Morrisson (2002)) or the multipolarity of the world economy (World Bank (2011)). We present here a brief discussion of the main criticisms addressed to this data source, then expose the adjustments that were necessary for our own study.

3.1 Discussion of Maddison (2010)

It is fair to say that, in spite of its rigor and breadth, good part of the Maddison database results from crucial assumptions, and more so for the pre-industrial period.[5] This is due to the scarcity of direct observations in particular before the XIXth century, and one of the major merits of Maddison has been to detail and justify openly the choices he had to make while reconstructing population and GDP series back in time. This has unavoidably led to some controversies, in particular regarding the timing and extent of the European ascent (e.g. Bairoch (1993), Alam (2006)). As these assumptions affect our own study, they deserve a discussion. We present that discussion below, with a particular emphasis on China and Europe during the 1500-1820 period.[6]

In the Maddison database, most GDP series result from the combination of estimates of population and GDP per capita, in particular for the preindustrial period. Uncertainty affects both variables, even for periods which are not so distant in the past. For example, regarding the estimation of the Chinese population in 1600, in a recent book, Brook (2010) establishes a large interval, between 66 and 230 millions.[7] With a value of 160 millions, Maddison is roughly in the middle range. However, for the next reference year, 1700, he proposes 135 millions. Although it is generally recognized that this period is one of relative decline for China, this figure is clearly at the lower end of the interval. Lack of data also affects directly

[5] For a radical critique, see (Clark 2009).

[6] We focus on that case because of its importance in terms of the genesis of the great divergence. Another frequently debated point is the use of appropriate purchasing power parities to estimate real GDP during the last two centuries (see Federico (2009), Fukao *et al.* (2007) or Prado (2000)).

[7] Heijdra (1998, p. 438) proposes a much higher interval between 185 and 289 million.

the estimation of the African population which are at best guesstimates before 1900, or of the American population before the colonial period. In America, the first systematic demographic records exist from 1520s for central Mexico and from 1560s for the Andes (Newson 2006, p. 144).[8]

The reliability of GDP per capita data is even more subject to debates. Maddison relies on deviations from estimated subsistence level, GDP per capita level in 1820 as well as best informed assumptions regarding growth rates between reference years. Between 1500 and 1820, he chooses an annual growth rate of GDP per head of 0.14% for West European countries, 0.10% for Eastern Europe, and zero percent for Africa and Asia (except for Japan and Indonesia). Regarding China, this pattern is consistent with the assessment of some renowned sinologists (Elvin (1973), Skinner (1985), see Deng (2000, p. 5)[9]) and more broadly with a traditional vision of the world opposing Chinese immobilism to European dynamism. It is partly based on the work of Perkins (1969) on Chinese agriculture, suggesting that China was able to accommodate for a large increase in population without any significant change in income per capita.

Although consistent with a common view, these income per capita figures have also been seriously challenged by the literature. According to Pomeranz (2000, 2005, 2008, 2011), until about 1750, China's Yangzi delta might have experienced income per capita levels quite similar to those of the most developed European regions.[10] Ma (2008) corroborates the usefulness of a regional approach at the very time when Rosenthal and Wong (2011) as well as Parthasarathi (2011) reject the idea of a Chinese or an Indian stagnation facing with a European growth. In his review, Federico (2002) argues that Maddison probably overestimated long run growth rates of GDP per capita in Europe between 1500 and 1820 (or even on longer term). This is in line with the figures proposed by van Zanden (2001), Alvarez Nogal and Prados de la Escosura (2007), Malanima (2009) and Broadberry *et al.* (2011).[11]

[8] Estimates of the size of the native population in 1492 America range from 8 to 90/113 million ; Newson (2006) follows the estimates of 53,9 million proposed by Denevan (1992) and based on a detailed review of regional research (estimated margin of error according to Denevan: ± 20%) and Maddison adopts 19.8 million for 1500.
[9] Maddison (2006, p. 631) qualifies his interpretation as « a hybrid of Needham and Elvin ».
[10] For Maddison's answer to Pomeranz, see Maddison (2006, p. 629-631).
[11] The 2011 (March) version of their paper includes a table of estimations of GDP per capital levels (in 1990 international dollars) for Northwest Europe and some other European countries. All these estimations (from various authors) are consistent with slower rates of growth and higher GDP per capital levels before 1820. The 2011 (December) version of their paper do not anymore include this table.

Resolving these controversies is an ongoing debate which is beyond the scope of this paper. Suffice here to note that altering key assumptions may result in important differences regarding the timing and geographical pattern of the great divergence.[12] Maddison himself duly recognized these difficulties (and actually adjusted downwards his early estimates of European growth)[13], but did not consider them "as a serious challenge" at the time (Maddison (2004, p. 34)). Since then, and to the best of our knowledge, although some of these caveats may justify reconsideration in specific cases, there has been no attempt to adjust the complete Maddison database in a systematic and consistent way. In any case, while interpreting results, we will focus on the less debated 1820-2010 period.

3.2 Data preparation

Regarding centers of gravity calculations, a first problem of the Maddison database is that data are reported at the country level, not at the cell level. We deal with that by spreading national (Maddison-based) population and GDP across grid cells using the shares obtained from the G-Econ database. The latter provides geo-economic data at the grid cell level (with a 1 degree-width in terms of both latitude and longitude) every five years over the 1990-2005 period (see Nordhaus et al (2006)). For all years within that period, we use a weighted average of the two closest years (e.g. 80% of the 1995 share and 20% of the 2000 share for year 1996), and 1990 shares for all years before that. This last assumption is critical, but with a limited impact for the majority of countries, and it is unavoidable anyway given data scarcity.

Second, going back in time before 1950, disaggregated data become unavailable for an increasing number of countries, subregions or regions, even if they always remain available at the continental level. To complete the missing data on population and GDP we follow a two-step « bottom-up » procedure. Starting from country-level data we: (i) interpolate between available years and extrapolate applying continental growth rates (ii) adjust proportionately the figures obtained from step (i) if they do not match the reported subregional total. We repeat the same steps when going up from subregions to regions and from regions to

[12] For example, selecting lower growth rates of GDP per head in Europe over the 1500-1820 period would imply that European GDP per capita levels prior to 1820 have been underestimated (which suggests that the divergence occurred before than previously considered). Higher European GDP per capita levels prior to 1820 could also go hand in hand with underestimation of Asian GDP per capita before 1820. Broadberry and Gupta (2011) and Bassino *et al.* (2011) tend to suggest that in a minor way.

[13] See Maddison 2001, p. 244; 2004, p. 22-23.

continents. The obtained database is thus consistent with originally reported continental figures.[14]

4. Results

We first comment overall results at the worldwide level, then we decompose changes into between-continent and within-continent variations. Finally, we propose a structural analysis based on several subperiods.

4.1 Overall results

Figure 1(a) reports the evolution of the projection of the WDCG and WECG during the first nine tenth of the sample period (1-1820). Both centers locate quite close to each other, between Northern Pakistan and Eastern Tajikistan, reflecting the absence of large differences of GDP per capita across continents. The fact that these centers locate in weakly populated areas should not come out as a surprise. It simply illustrates the fact that those are weighted averages, and that Asia, in particular China, was predominant in terms of demographic and economic weight during that period. Over time, the WDCG tends to shift to the North-East, and the WECG to the North. Those shifts will be analyzed in more detail in section 4.3. Suffice here to note that they are relatively modest, and to remind that the older the period, the poorer data reliability.

Figure 1(a): World centers of gravity (1-1820)

The next two centuries are characterized by more dramatic changes, in particular for the WECG (figure 1(c)), which exhibits less inertia than the WDCG (figure 1(b)). The XIXth century coincides with a remarkable migration of both population and economic centers towards the North-West. The shift is clearly more pronounced for the WECG, which illustrates the « great divergence » brought in by the industrial revolution. The trend is altered during the XXth century, since 1945 for the WECG, which heads back towards the North-East

[14] A final adjustment consisted of extending the database to 2009 and 2010 by using the national growth rates estimated by the World Development Indicators (2011). A number of other minor adjustments are described in Appendix A.

first, then to the South-East, and as early as 1920 for the WDCG, which heads South, then South-West.

Figure 1(b): World demographic center of gravity (1820-2010)

Figure 1(c): World economic center of gravity (1820-2010)

These overall trends offer a new vision of the acceleration of world economic history, with critical turning points in both demographic and economic terms during the last century. They are complemented by figures 2(a) and 2(b), which report the length (in km) and the average speed per decade (in km per year) of both centers of gravity during the last 200 years (both variables remain fairly constant over the 1-1820 period). Regarding length, there is a strong downward trend for both gravity centers until 1950, and since then, a relative constancy for the demographic center and a continuous decline up to 2000 for the economic one. This suggests that the industrial revolution was followed by a more even distribution of both human population and economic activity across the earth's surface.[15] Regarding speed, as already noted above, the WECG exhibits a much larger rate of change, with an acceleration of changes at the end of each half of the XXth century.

Figure 2: Length and speed of the world centers of gravity

4.2 Between or within-continent variation?

What are the main factors leading to the above-mentioned patterns? To get a better understanding of the underlying forces, we group cells into four continents: Africa, Asia (including Oceania), America and Europe. Then we estimate, for each subperiod, the share of the change which is due to variations between or within continents (see Appendix B for the detailed methodology). Results are reported in figure 3.[16]

Figure 3: Average between and within-continent effects

[15] It is also apparent that the length of the WDCG vector is larger than the length of the WECG vector. This can be explained by the fact that the angle between the two most opposed continental gravity centers (America and Asia) is larger in economic than in demographic terms, so that there are more compensation effects in the former than in the latter case.

[16] We also performed an alternative decomposition exercise based on ten rather than four regions. Results are robust and available from the authors upon request.

Whatever the nature of the underlying variable (population or GDP), between-continent variation turns out to be prevalent. The only exception is the 1700-1820 period, during which within-continent variation is more important in both demographic and economic terms (it is also more important between 1600 and 1700 for the WDCG). Thus, it makes sense to analyze changes in the location of the WECG/WDCG as basically driven by changes in continental shares in world population or output (see figure 4) rather than by changes in the distribution of those variables within continents.

Figure 4: Evolution of continental shares

To pursue along this line of interpretation, we need two additional pieces of information. Figure 5 provides the average length of the WDCG and WECD over three subperiods. There is not much change over time, and the most (less) concentrated continent is always Europe (America). Figure 6 represents the average location of continental centers of gravity over the same subperiods. In short, Europe and Asia locate North and South, while America and Asia locate West and East of the world gravity centers. Along with the continental shares reported in figure 4 and the "intuitive rule" defined in section 2.4, these average locations constitute the basis of the structural interpretation proposed in the following subsection. (for the specific contribution of each continent during the 1820-2010 period, see figures A5 and A6 in the Appendix.[17]).

Figure 5: Average length (continental concentration indices)
Figure 6: Continental centers of gravity: average location

4.3 Analysis by subperiod

4.3.1 Early phases (1-1820)

1-1500: A rather stable world

During much of that period, differences in GDP per capita across continents remain small, so that the evolution of continental economic shares almost mimics the evolution of

[17] For space reasons and also because changes are rather small, we do not report results for earlier years. Results are available upon request from the authors.

demographic shares. The first millennium is characterized by a great stability. The unique source of change is the small relative decline of Asia with respect to Africa, following the Arab expansion, and justifying the Eastern shift of both the WECG and WDCG which is apparent on figure 1(a). The next five hundred years (1000-1500) witness a reversal in the relative position of Africa and Europe.

1500-1820: The progressive ascent of Europe

The relative uprising of Europe and decline of Africa persist during much of that period, in particular in economic terms, sustaining a Northern shift of the gravity centers. However, this period is more difficult to interprete for two reasons. First, the trajectories of the WECG and WDCG begin to deviate, because of the emergence of larger differences in GDP per capita between countries and continents. Second, as mentioned in subsection 4.2, it is the only time interval during which within-continental figures matter, particularly at the end of the period, and essentially because of structural changes within the Asian and American continents.

The XVIth century is basically marked by the sharp decline of the American share in terms of both population and GDP. This is due to the native demographic and civilization’s collapse following European conquest and generates a shift of both the WECG and the WDCG to the East. The next two centuries are influenced by changes within Asia and America. From 1600 to 1700, a series of bad harvests, epidemics, rebellion and Manchu invasion provokes a decline of both population and GDP in China[18], followed by recuperation during the next century. This generates a Western sift of the continental gravity centers during the XVIIth followed by an Eastern shift during the XVIIIth (see figure 7), which translates in similar moves of the world gravity centers. Also, the development of North American settlements during the XVIIIth generates a substantial move to the North of the gravity centers of this continent (see figure 7), in particular for the economic one, and this shift is also apparent for the world gravity center.

Figure 7: Continental centers of gravity: changes over time

4.3.2 The rise of the West (1820-1913)

[18] The Chinese decay (minus 14% for both population and GDP) may have been overstated by Maddison, leading to exaggerated back and forth movements of the WECG/WDCG during the 1600-1820 subperiod.

The evolution in terms of demography is one of growing importance of Western countries and their offshoots. The Asian share in world population drops from 65% in 1820 to 55% in 1913. As a result, the WDCG steadily shifts to the North-West (see figure 1(b)), but at a decreasing speed (see figure 2(b)). The eve of World War I foreshadows a real turning point in demographic terms. Following its demographic transition, Europe reaches its peak in terms of world population share, while Asia reaches its minimum and Africa begins its rise. As will be discussed below, this will lead to a complete u-turn in terms of the trajectory of the WDCG.

The industrialization of Western Europe and the United States, and the de-industrialization of Asia are the major trends characterizing that period. It leads to the great divergence, i.e. a lasting and widening gap in terms of GDP per capita. According to the Maddison data, the ratio between European and Asian GDP per head rises from 2 in 1820 to 5 in 1913, the corresponding ratios for the USA at the same years being 2.2 and 7.6 respectively. In terms of economic shares, Europe exhibits the strongest increase at the beginning of the period, then its share stabilizes around 1870, while America's share is still growing strongly. Conversely, the share of Asia in world GDP plummets, dropping from 60% in 1820 to less than 30% in 1913 (Asian GDP per head even decreases during the 1820-1870 subperiod). As a result, the projection of the WECG shifts to the North-West (see figure 1(c)), as for the WDCG, but at a speed which is several orders of magnitude larger, and increasing (see figure 2(b)).

4.3.3 The world wars and the progressive decay of the West (1913-2010)

1913-1945: America takes the lead

The largest toll in terms of deaths during WWI being in Europe, it is not surprising that the WDCG shifts back to the East. During the following decades, the European population share first stabilizes then drops again following WWII, while the American and African shares are constantly on the rise. This leads the WDCG to describe first a Western then Southern trajectory. As Europe is by far the most concentrated continent in terms of population, and America the less concentrated one (see figure 5), this explains the continuous decline in the concentration index exhibited by figure 2(a).

In economic terms, Europe suffers a first drop in its world GDP share after WWI, benefitting America, while the Asian share remains roughly constant, essentially thanks to the rise of Japan. This generates a relatively small shift of the projection of the WECG to the West. During the next two decades, even if large economic fluctuations affect the major world economies, there is no clear trend, and the projection of the WECG remains located on the Norwegian territory (see figure A4 in the Appendix). The Second World War leads to more radical changes. Economic activity is boosted in the US, and severely constrained in Europe and Japan. The European and the Asian shares drop significantly, while the American share reaches its climax, with more than 40% of world output in 1945. This corresponds to the most occidental location of the WECG (at the North-West side of Iceland) and the largest average speed (see figure 2(b)) over the whole period.

1945-2010: Europe, then America in retreat

The evolution of continental shares in world population is in two phases. Until 1970, all continents are on the rise, except Europe. This explains the southern trajectory of the WDCG, as the Asian and American continents roughly compensate each other in terms of longitude. Since 1970, as the American share stabilizes, one could expect a shift to the South-East. However, the reverse emerges on inspection of figure 1(b). There are two explanations for that. First, the rise of the African share is stronger than the Asian one, due to the fact that the demographic transition is more advanced in the latter continent (in particular in Japan, where the ageing of the population starts in the 1990s and proceeds fast since then). Second, as illustrated by figure 3(a), this subperiod is also characterized by significant within-continent effects, and as it turns out, following the ageing of the Japanese and Chinese populations, there is a clear Western shift of the continental demographic center of gravity in Asia (see figure 7).

Abstracting from the huge swings implied by WWII and its direct aftermaths, the 1950s represent the real turning point in economic terms. Having reached an extreme level in 1945, America's share in world GDP quickly drops to 38% in the next five years, then gently decreases towards 32% until 2000. Immediately after WWII, Europe climbs back to represent again more than 40% of world GDP at the beginning of the 60s. This coincides with a WECG on the Eastern side of Iceland, and with the minimum of world GDP ever achieved by Asia (less than 20%). From that point onwards, Asia will catch up, and the WECG will shift East.

It may appear surprising at first that the trend reversal occurs in the 50s rather than three decades later, i.e. after the takeoff of several Asian economies in terms of GDP per capita growth. This is due to the fact that shares are based on total GDP figures, not on per capita ones, that the European population share is declining since 1913, and that the American one stabilizes at the end of the 50s.

The Eastern shift since 1950 is roughly in three phases of accelerating speed. The first two phases are characterized by an almost stable share of America, and a progressive decrease of the European share, relatively moderate during the 60s and 70s (upsurge of Japan), and more pronounced during the 80s and 90s (progressive takeoff of other Asian economies, with no long-run consequences of the 1997 crisis). This corresponds to the long North-East shift of the WECG until it reaches its most northern location, at the North-East of the Scandinavian Peninsula. The third phase starts in 2000, marking a new break in the trend, and is still ongoing. With the American share in world GDP decreasing at more or less the same speed as the European one, the WECG stops its Northern shift and heads South-East at an accelerating speed. Note that our data do not allow for a full account of the consequences of the 2008 crisis (this is why we do not report the original 2030 forecast included in the Maddison database). Anticipating future trends, as emerging economies have exhibited more resilience than mature ones, a perpetuation of the reported trend of the third phase seems probable.

5. Conclusions

This paper offers a condensed view of the geographic distribution of world population and economic activity in the long run. Applying the concept of the center of mass (unique point that encapsulates the whole distribution) to population and GDP and projecting it to the Earth surface allows to identify important shifts in the worldwide balance of power with respect to these two variables.

Results show that following the industrial revolution, the demographic and economic centers of gravity, which were located close to each other in Central Asia, experience a strong westward shift during the XIXth century. The journey is however shorter for the demographic center in terms of both distance and time, as it stops its westward progression in Central Kazakhstan in the 1920s already, while the economic center shifts as far away as the Western shore of Iceland in 1945. Since then both centers have come back closer to their initial locations, following the catching-up process of the Third World, but the economic center is located further North while the demographic center is heading South, reflecting the increasing relative poverty of Southern (sub)continents.

These boomerang-like trajectories upon the earth surface offer new insights to assess long run demographic and economic trends. On the one hand, they show that seemingly important dates in human history such as world wars or oil shocks, that affected regions in different ways, did not add much in fact to the global power balance. On the other hand, results allow to identify specific periods, like the 1920s, 1950s or 2000s, relatively neglected so far, but which correspond to critical changes in trends. Although only two dimensions of power are measured here (for example, factors of soft power are out of the range of this paper), and data quality can be discussed, these insights are of primary importance for the understanding of world politics and international negotiations.

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Figure 1 (a): World economic and demographic centers of gravity (1-1820)

WECG : ■ - - - ▸ WDCG : ● ⟶

Figure 1 (b): World demographic (1-2010) center of gravity

WDCG : ⟶ ○ : 1-1900 ◉ : 1901-1950 ● :1951-2010

Figure 1 (c): World economic center of gravity (1-2010)

WECG : ━ ▸ □: 1-1900 ◘ : 1901-1950 ■ :1951-2010

Figure 2: Length and speed of the world centers of gravity (km, 1820-2010)

(a) Length (km) (b) Average speed (km/year)

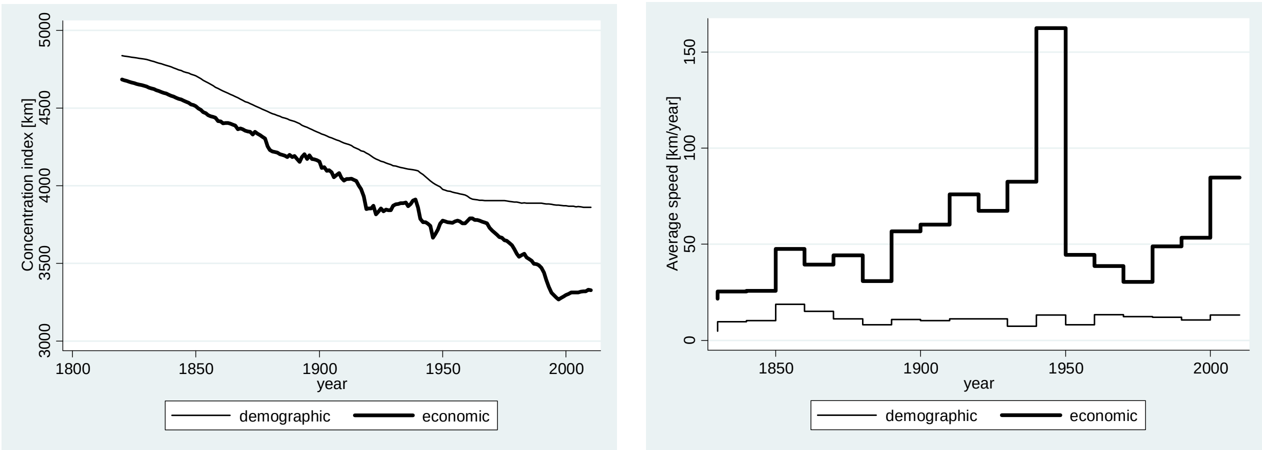


Figure 3: Average between and within-continent effects

(a) WDCG (b) WECG

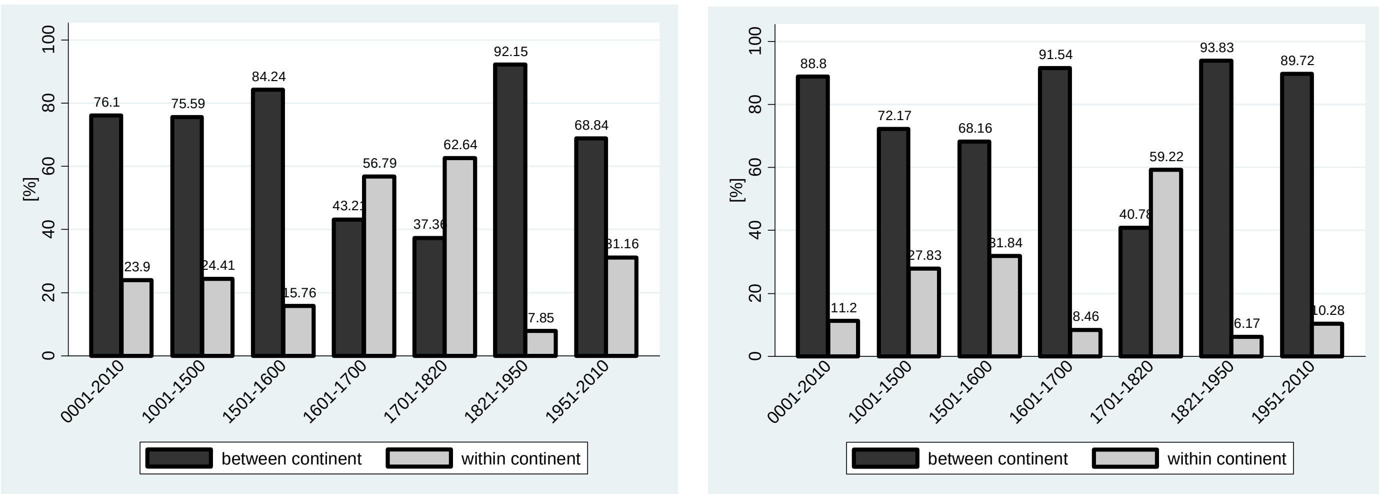
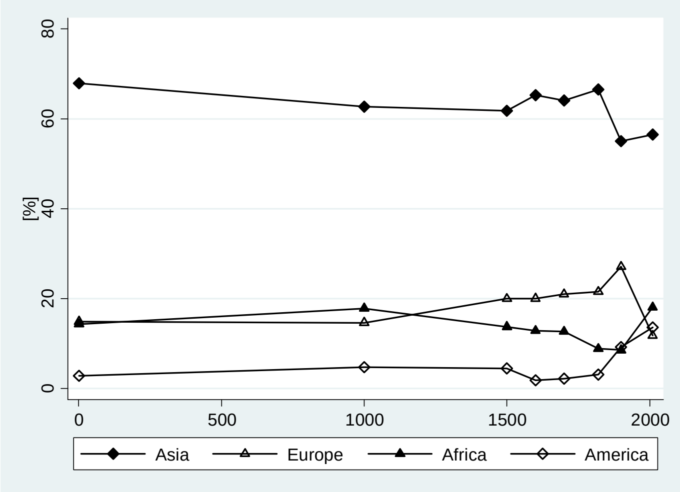


Figure 4(a): Evolution of continental shares (1-2010)

Population



GDP

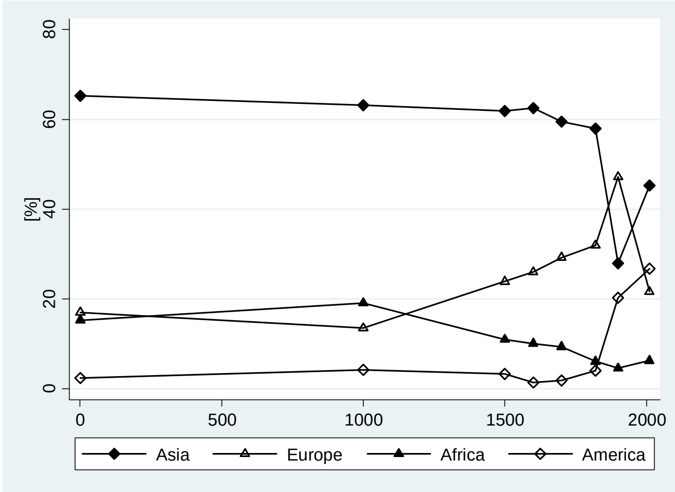
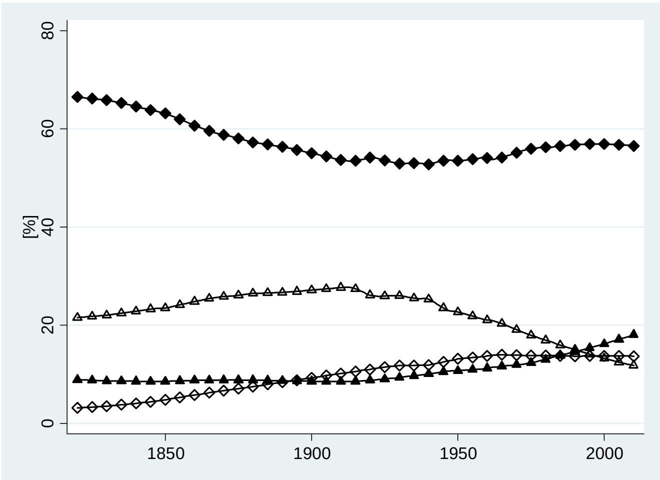
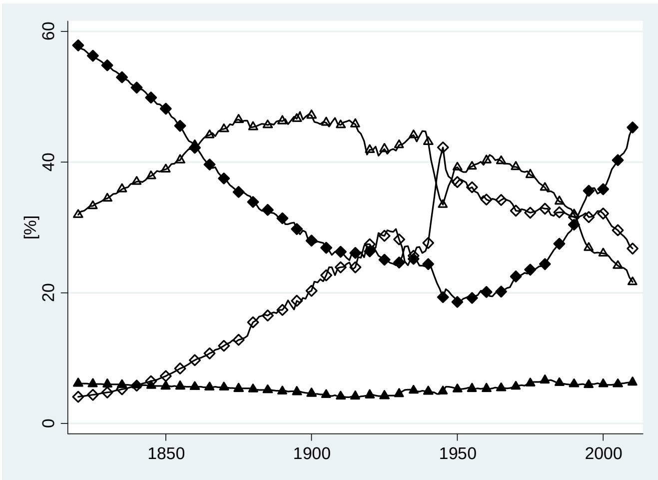


Figure 4(b): Evolution of continental shares (1820-2010)

Population



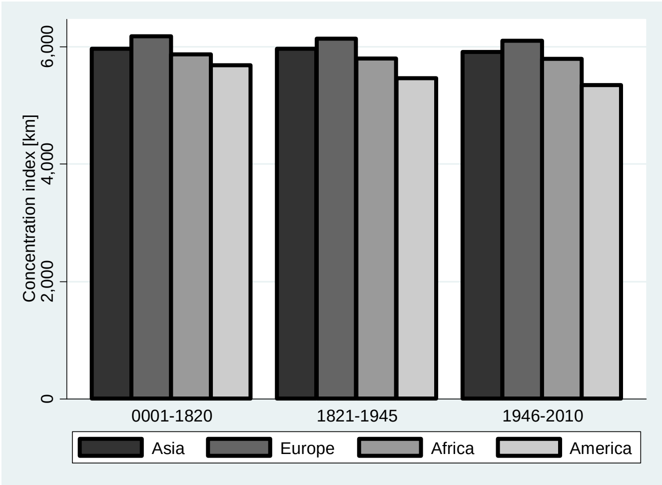
GDP



Note : see legend of table 4(a)

Figure 5: Average length (continental concentration indices, %, 1820-2010)

(a) WDCG



(b) WECG

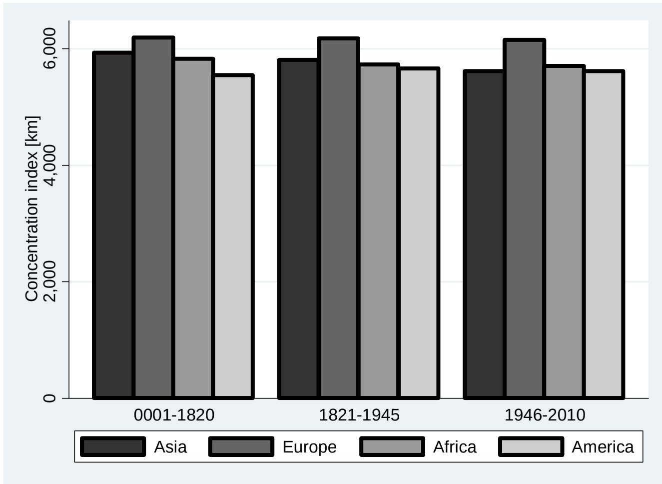


Figure 6: Continental centers of gravity: average location

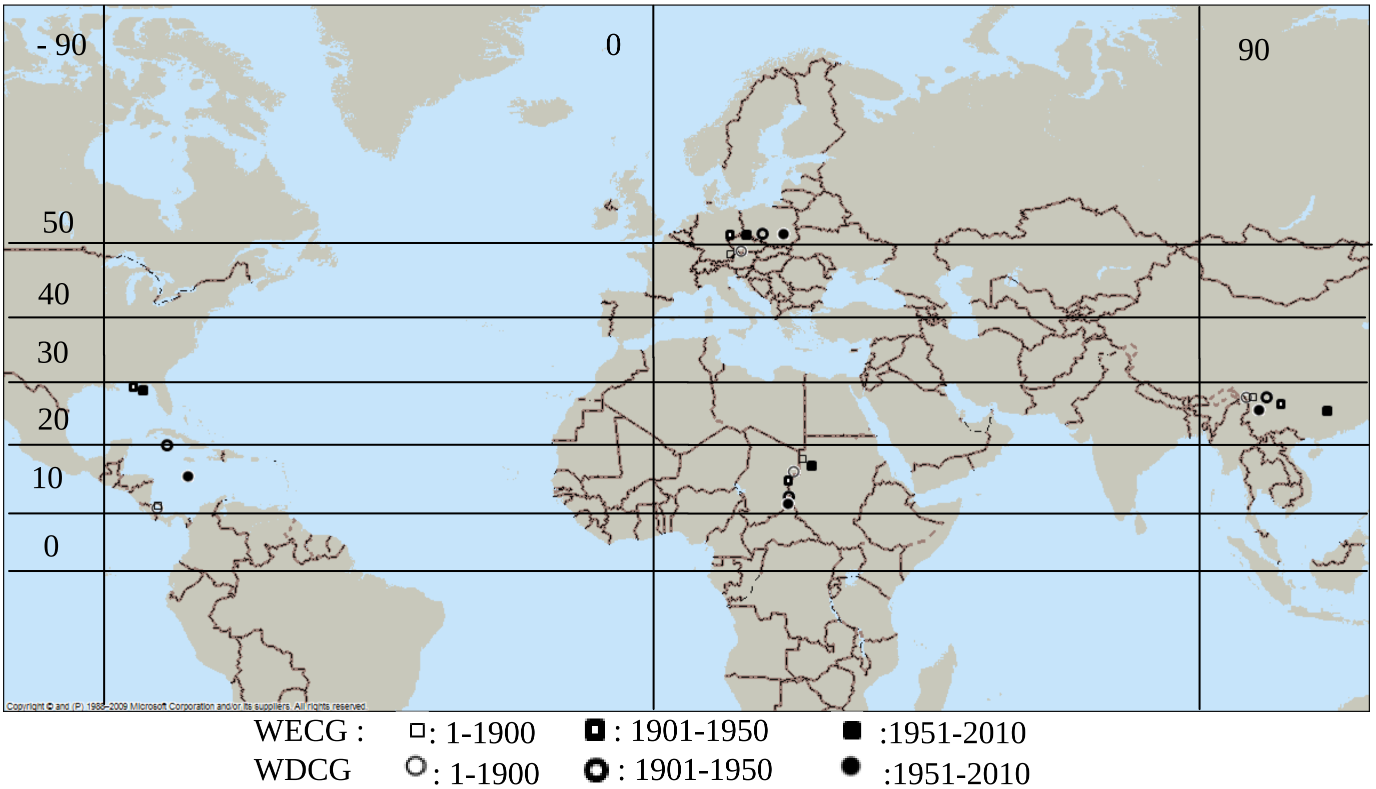


Figure 7: Continental centers of gravity: changes over time

Geographic: ▲ Economic □: 1-1900 ■: 1901-1950 ■ :1951-2030
Demographic ○: 1-1900 ●: 1901-1950 ● :1951-2030

Note: Continental centers for Europe and Africa appear in figure A3 in the Appendix.

Appendices to

“The Rise and Fall of the West: a Geographical Perspective”

Appendix A: Completing the Maddison database 1-2010

The database has been completed following a three-step procedure (for both population and GDP):

(1) Adapt classification and correct dubious values or straightforward errors (see details below)
(2a) Interpolate country-level data across all missing years. Extrapolate forward or backward applying the same growth rate as the corresponding continental total
(2b) Calculate subregions totals. If they do not match the originally reported data, change interpolated values proportionately so that they do. Interpolate again on the modified values.
(3) repeat steps (2a) and (2b) for regions and continents

Specific adaptations and corrections

Yugoslavia 1991-2008. The population and GDP of Yugoslavia that are taken into account in the continental total for “Total 7 East European countries” after 1990 are rounded, which generates inconsistency with the sum of constituent countries. Continent and world totals are adjusted.
West Asian countries in 1989. Recalculation of the GDP total for "Total 15 West Asian countries" in 1989 (the originally reported figure is the replication of the one for 1988). World and continental totals are adjusted accordingly.
Caribbean population 1913-1950. For "Total 21 small Caribbean countries" there is a population break in 1950 (and no country population before that). We interpolate over 1913-1950 and adjust the world and continental totals.
Afghanistan & Cyprus population in 2009. This year, there is a jump of more than 4 million people for Afghanistan and also a jump for Cyprus. We correct that by applying to 2008 the same growth rate as for 2007-2008 and adjust the regional, continental and world totals.
Asian population total in 1900. The reported growth rate of Asian population over 1870-1900 is 13.6%, while the growth rate of the region “Total 16 East Asian countries”, which represents 92.82% of the continental total in 1870, is 15.3%. This implies a decline of the population by 9.1% (5 million people) for the other two regions of the continent. To avoid this seemingly nonsense, we extrapolate the share of the large region between the two closest years for 1900 (i.e. 92.82% in 1870 and 92.20% in 1913), which gives 92.39% or a new estimated continental total of 890’960’664 people (instead of 873’324’000). We adjust the world total accordingly.
Including missing population data in totals for three countries in East Asia. For Nepal, Singapore and Hong Kong, between 1913 and 1949, there is always at least one of these three missing so that the totals are calculated on less than the full number of countries. So we interpolate the missing data for those three countries and adjust the totals.
GDP data in 2009. Apply the real growth rate obtained from the WD development indicators to 2008 figures.
Population and GDP data in 2010: Apply the real growth rate and population growth rate obtained from the WD development indicators to 2009 figures.
GDP data in 2030 (not used). We assume GDP per capita will grow at half the corresponding continental rate over the 1990-2010 period (as a very crude way to control for the aftermaths of the crisis and the depletion of natural resources). Then combine population and GDP per capita estimates to infer GDP in 2030.

Partitioned countries

The objective is to re-establish *territorial consistency* i.e. the same geographical meaning over the years. Three cases:

Ireland and United Kingdom: Before 1921, the population of Ireland is both included in that of the UK (and incorporated in the subregion total) and reported separately (but not included in the other subregion total). Following the partition in 1921 there is a drop in the population of IRL (which loses Northern Ireland, around 1.3 millions) and the

UK (which loses Southern Ireland, around 2.7 millions). From 1921 both countries are considered in the totals of the corresponding subregions. Correction for that:

- use 1500 share to complete Irish population in 1, 1000
- consider that the population decreases from 1920 to 1921 of both countries are representative of the population of Southern and Northern Ireland and infer from that the Southern and Northern shares in the total.
- use the shares obtained in the previous point to reduce the UK (by the Southern population) and IRL (by the Northern population) before 1921, and adjust the regional totals accordingly (no need to correct "Total Western Europe" as Ireland is not considered in the original sum before 1921).

For GDP the situation is similar, except that GDP for Ireland is missing in 1920 and UK GDP is available every year. So we:

- use 1500 shares to complete IRL GDP in 1, 1000
- use our reconstructed population series to calculate the average GDP per capita for the total of UK+IRL over the entire period where data is available (i.e. discrete years until 1830 then a complete series to 2008).
- assume that Irish GDP per capita is identical across Southern and Northern Ireland, which allows to reconstruct GDP per capita data for "corrected" countries in "peak years" 1820, 1870 and 1913.
- from the previous points, interpolate Irish GDP per capita over the 1820-1921 period and deduct from that Irish and UK GDP.
- Reconstruct corrected GDP series prior to 1921. Adjust the regional totals accordingly (no need to correct "Total Western Europe" as Ireland is not considered in the original sum before 1921).

East Timor and Indonesia: Until 1999, the population of this country is both included in Indonesia (since year 1) and listed separately (since year 1882, but not considered in totals). Correction:

- inpute 1882 share to estimate East Timor population before that date
- interpolate 2000-2008 for East Timor
- assume same growth rate over 2009-2030 to complete East Timor value for 2030
- substract East Timor from Indonesian total for all years before 2000
- recalculate the regional totals before 2000 (no need to correct at the continental level).

For GDP, the situation is similar, but with there is no separate data for East Timor. Moreover, the subregional total for "30 East Asian countries" before 1950 is only available for 3 years: 1820, 1870 and 1913. Correction:

- assume that East Timor GDP per capita is 3 times smaller than the Indonesian one (order of magnitude from the WDI for year 2000 in PPP)
- use above assumption and previously estimated population data to estimate GDP per capita for both countries prior to 2000
- substract East Timor from Indonesian total for all years before 2000
- recalculate the regional totals before 2000 for all relevant years i.e. 1950-1999 plus 1820, 1870 and 1913 (no need to correct at the continental level).

Pakistan, Bangladesh and India. Those are parts of the same country prior to 1950. Moreover, for some unexplained reason reported population and GDP data for India in 1947-1949 do not include Pakistan and Bangladesh. Correction procedure:

- extrapolate backward the 1947-1950 trend to infer India population and GDP in 1946
- combine that information by interpolating the shares of Pakistan and Bangladesh to complete population and GDP of those two countries between 1946 and 1950 avoiding any "bump" in the trajectory.
- split India into its three components prior to 1946 applying 1946 shares.
- recalculate the regional, continental and world population totals in 1947-1949

Appendix B: Computation of the average between and within effects

We start from equation (4) of the main text, which decomposes the change in the *x* coordinate of the gravity center into between-continent and within-continent changes. The objective is to aggregate this decomposition over the three dimensions and all years of a given subperiod.

First, note that, apart from $\overline{s}_{vt}^{c}$, all terms in equation (4) can be either positive or negative. If we limit the analysis to dimension *x*, year *t*, this is not really a problem because what we want is to capture the net contribution of each effect to the overall net effect. By dividing the whole equation by Δx_{vt}, we can express the between and within variations as a percentage of the net total variation, whether or not some terms are negative. For example, if $\Delta x_{vt} = -0.5$ while the first and second term on the right hand side are -1 and 0,5 respectively, that means that the between (within) effect is worth 200% (-100%) of the net total effect, the negative sign indicating that the within effect acts in the opposite direction of the total effect. Of course each right-hand side element is itself a sum which hides potential compensations across continents. But what we are interested here is only the net effect at the global level.

What is more troublesome is that there are three dimensions (*x,y,z*) and many years, which may lead to undesired compensations. For example, across dimensions, if $\Delta x_{vt} = -0.5$, $\Delta y_{vt} = -0.5$ and $\Delta z_{vt} = 1$, it would not make sense to simply sum up those three numbers, and suggest a zero net change, while those figures do indicate a change in the location of the gravity center. Similarly, across years, if the trajectory of the gravity center describes a loop coming back to its initial location, we are not interested by the net change in location (which is zero) but by the sum of all individual yearly changes. To control for these undesired compensations, what we propose is to weigh each dimension- and year - specific effect by the share of that particular dimension cum year combination in the sum of the absolute value of all combinations.[1] More precisely, for any given year *t*, we define the between-continent (BC_{vt}) and the within-continent (WC_{vt}) variation the following way:

$$BC_{vt} = \sum_{c=1}^{4} \Delta s_{vt}^{c} (\theta_{vt}^{x} \frac{\overline{x}_{vt}^{c}}{\Delta x_{vt}} + \theta_{vt}^{y} \frac{\overline{y}_{vt}^{c}}{\Delta y_{vt}} + \theta_{vt}^{z} \frac{\overline{z}_{vt}^{c}}{\Delta z_{vt}}), \quad WC_{vt} = \sum_{c=1}^{4} \overline{s}_{vt}^{c} (\theta_{vt}^{x} \frac{\Delta x_{vt}^{c}}{\Delta x_{vt}} + \theta_{vt}^{y} \frac{\Delta y_{vt}^{c}}{\Delta y_{vt}} + \theta_{vt}^{z} \frac{\Delta z_{vt}^{c}}{\Delta z_{vt}}) \tag{A1}$$

where θ_{vt}^{x} is the share of dimension-x in the sum of absolute changes, i.e. $\theta_{vt}^{x} = |\Delta x_{vt}| / \left[|\Delta x_{vt}| + |\Delta y_{vt}| + |\Delta z_{vt}| \right]$, and similarly for θ_{vt}^{y} and θ_{vt}^{z}. This satisfies $BC_{vt} + WC_{vt} = 1$.

The average over the entire sample period is obtained by:

$$BC_{v} = \sum_{t} \theta_{vt} BC_{vt} \ , \ WC_{v} = \sum_{t} \theta_{vt} WC_{vt} \tag{A2}$$

where θ_{vt} is the share of year *t* in the sum of absolute changes, i.e. $\theta_{vt} = \left[|\Delta x_{vt}| + |\Delta y_{vt}| + |\Delta z_{vt}| \right] / \left[\sum_{t} \left[|\Delta x_{vt}| + |\Delta y_{vt}| + |\Delta z_{vt}| \right] \right]$. Again we have $BC_{v} + WC_{v} = 1$.

[1] We also analyzed the alternative of using squared terms instead of absolute values. Results are robust, and available upon request.

Appendix C: Interpretation of the continental contribution

This appendix clarifies the interpretation of the average contribution of continent *c* calculated from equation (4). The objective is to identify the cases where the **intuitive interpretation rule** suggested in the main text (e.g. when the continental center is East of the world center, the continental contribution on longitude is positive) does not apply.

Whatever the effect, the continental contribution can be interpreted as the impact (on latitude or longitude) of adding a new vector, $\lambda\vec{b}$ (the continental gravity vector times the change in continental share in the case of the between effect, the continental shifting vector times the continental share in the case of the within effect), to an original vector, $\vec{a}$ (the world gravity center). That is, if we add $\lambda\vec{b}$ to $\vec{a}$, what happens in terms of latitude and longitude?

Latitude changes

To illustrate why latitude changes may break the "intuitive rule", consider **figure A1** (next page), where $\vec{a}$ represents the initial world gravity center and $\vec{b}$ the gravity center of continent *c*. To simplify, we have assumed that both vectors locate in the same (*y,z*) plane (i.e. the plane containing the 90° Meridian). This is a special case but quite an important one. Indeed, we can say that figure A1 depicts very roughly the situation at the beginning of the XIXth, with continent *c* being America, with a lower latitude than the world's center of gravity ($\varphi_b < \varphi_a$). During this century, America's share in world GDP has increased by around 20%. Thus, according to the intuitive rule, we would expect a decrease in the latitude of the world gravity center following that change. However, due to the particular location of the continent, the reverse occurs: as can be verified in **figure A1**, adding $0.2\vec{b}$ to $\vec{a}$ *increases* φ_a.

The counter-intuitive pattern represented by **figure A1** is quite extreme because we have imposed a maximum difference in longitude between $\vec{a}$ and $\vec{b}$ (180°). The only continent which is reasonably close to that situation is America. For all other continents, the ultimate outcome will depend on both the difference in latitude and the difference in longitude between $\vec{a}$ and $\vec{b}$.

Longitude changes

As changes in λ are not relevant in that case, assume that $\lambda = 1$. Consider **figure A2** (next page), where the *x*-axis (*y*-axis) represents the projection of the Greenwich Meridian (the 90° Meridian) on the equatorial plane, while $\vec{a}'$ and $\vec{b}'$ represent the projections of the $\vec{a}$ and $\vec{b}$ vectors on the same plane. All origin-centered vectors located on the right (left) of the *x*-axis, i.e. eastward (westward), correspond to a positive (negative) longitude. In the specific case of **figure A2**, both vectors have a positive longitude, with $\varphi_b > \varphi_a$, so that $\varphi_c > \varphi_a$. In other words, the intuitive rule applies, i.e. as the additive vector locates on the East of the original vector, the final vector moves East. This will be so for any $\vec{b}$ vector for which $\varphi_b > \varphi_a$. Conversely, if $\vec{b}$ locates on the West of $\vec{a}$, and if $-(\pi - \varphi_a) < \varphi_b < \varphi_a$, the final vector moves West. The only exception, or "counter-intuitive" case with respect to the simple rule, is when $-\pi < \varphi_b < -(\pi - \varphi_a)$ (i.e. $\vec{b}$ in the shaded area). In this case, $\vec{b}$ has a negative longitude but has a positive influence on the longitude of the final vector, because $\tilde{\vec{b}}$ locates on the left of the *x*-axis, but on the right of the *a*-axis.

In sum, regarding longitude, the intuitive rule applies, except when the difference in longitude between the original and the additive vector is larger than 180°.

Figure A1: A "counter-intuitive" change in latitude

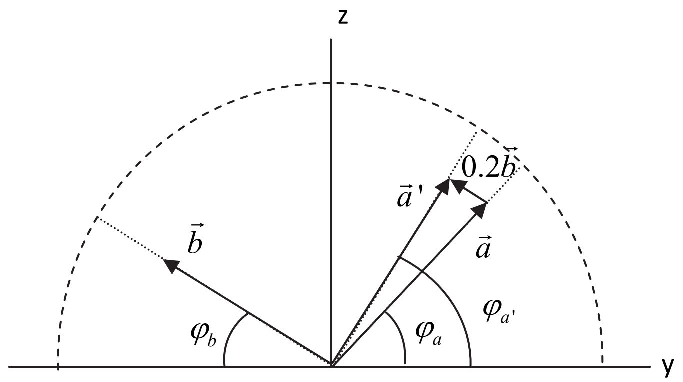


Figure A2: Changes in longitude

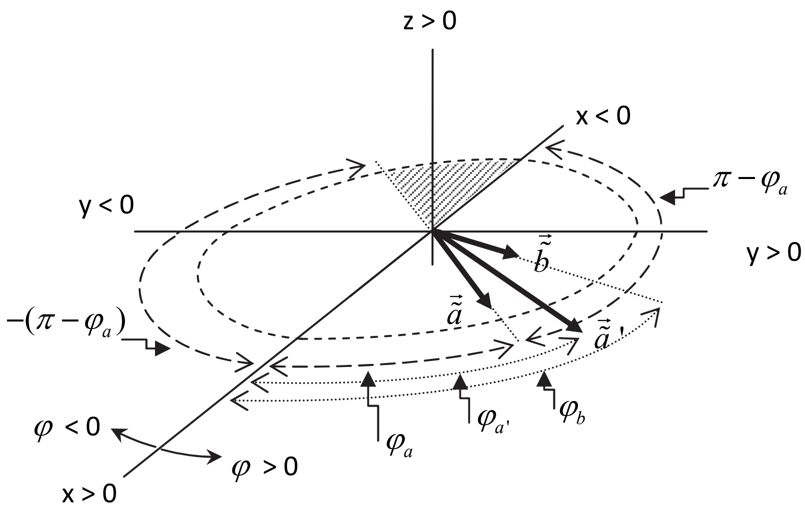


Figure A3: Continental centers of gravity: changes over time

Geographic: ▲ Economic □: 1-1900 ◘: 1901-1950 ■: 1951-2030

Demographic ○: 1-1900 ◉: 1901-1950 ●: 1951-2030

Note: Continental centers for Asia and Europe appear in figure 7 in the main text.

Figure A4: World economic center of gravity: 1900-1990

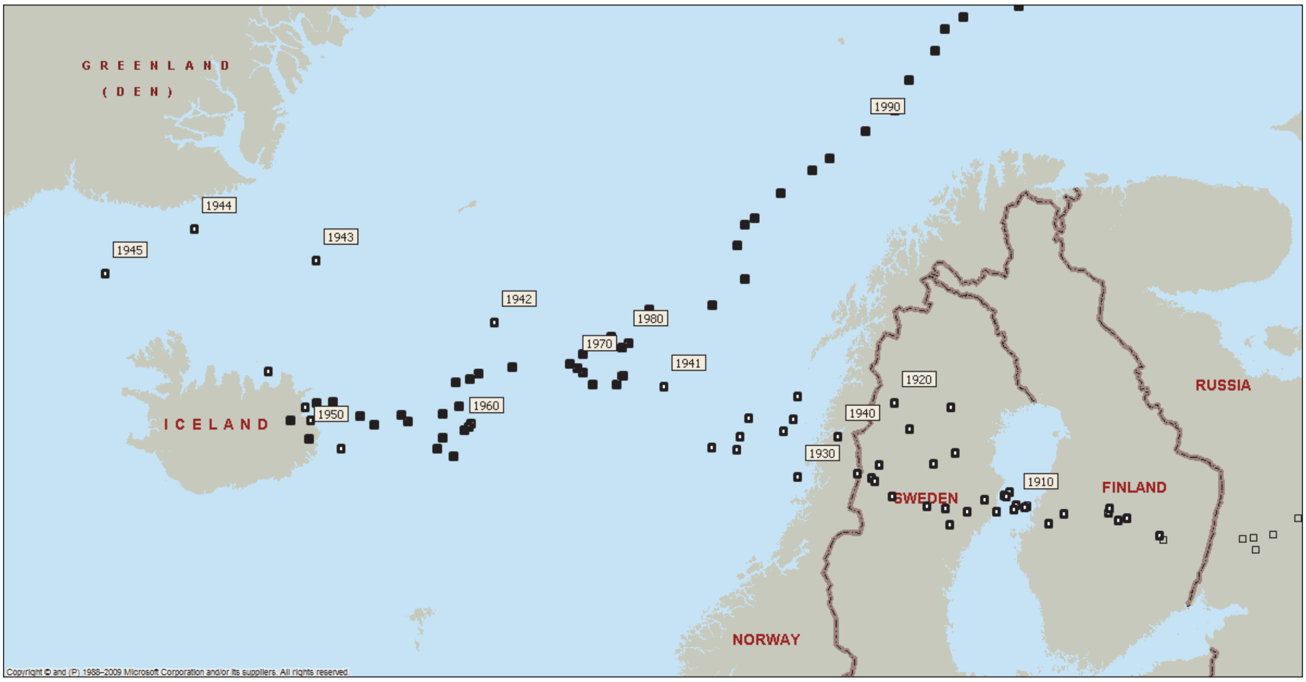
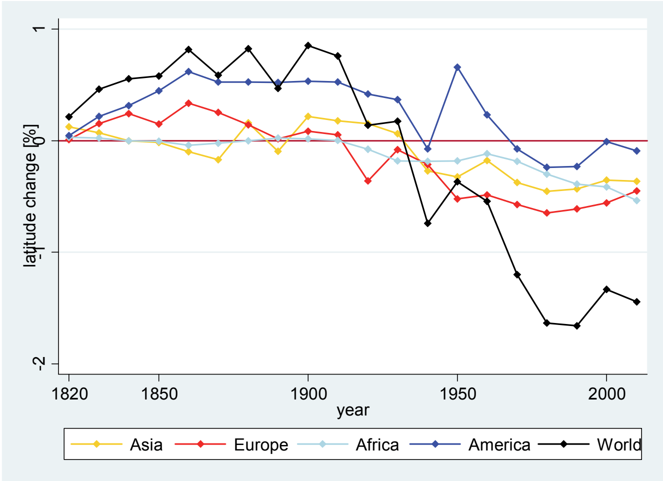
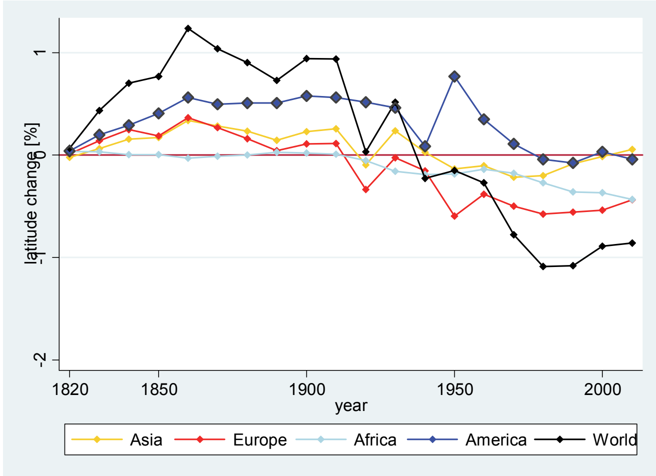


Figure A5: Contribution of each continent to changes of the WDCG

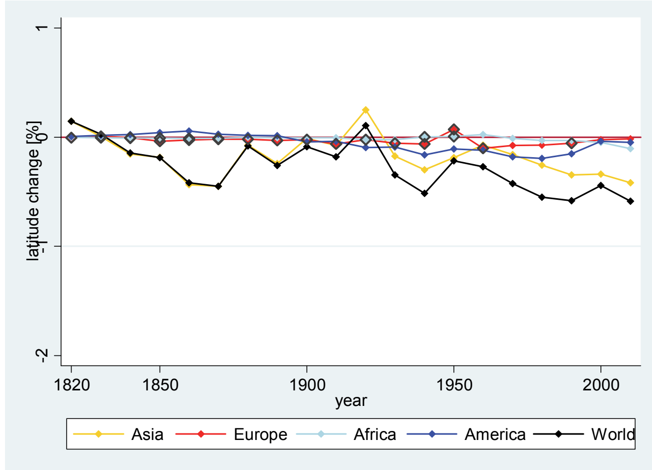
LATITUDE: TOTAL CHANGE



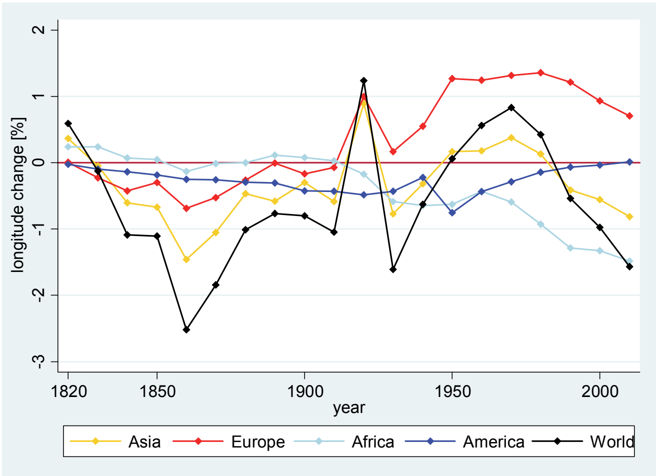
BETWEEN VARIATION



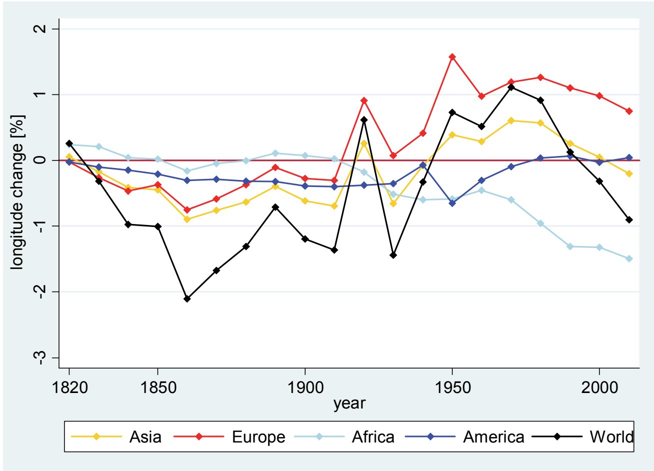
WITHIN VARIATION



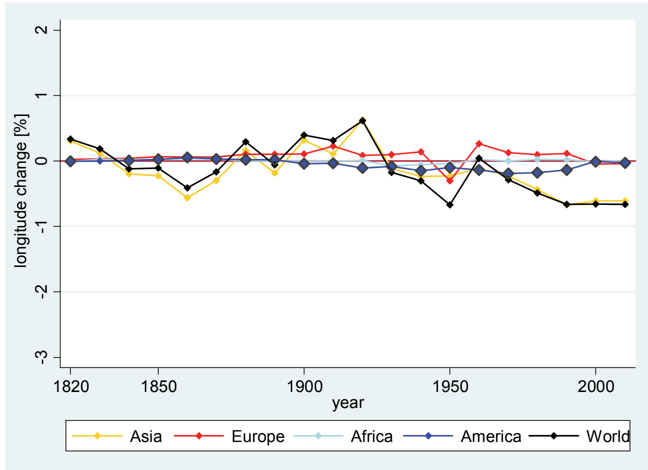
LONGITUDE: TOTAL CHANGE



BETWEEN VARIATION



WITHIN VARIATION



NB : black-circled diamonds correspond to counter-intuitive cases

Figure A6: Contribution of each continent to changes of the WECG

NB : black-circled diamonds correspond to counter-intuitive cases