

Is the World's Economic Center of Gravity Already in Asia?*

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Abstract

This paper proposes a simple measure of the World's Economic Center of Gravity (WECG) based on national GDP figures and the geographical location of the world's most important cities. This measure makes it possible to characterize the location of economic activity around the globe. It turns out that, over the 1975-2004 period, the WECG has shifted towards Asia, and the location of economic activity has become more evenly spread. On average, the distance to the WECG, which is highly correlated with the remoteness indicator frequently used in the trade gravity literature, has decreased more in Asian cities (-12%) and increased more in European cities (+16%).

JEL Classification numbers: F01

Key Words: Geographical location of economic activity, center of gravity, spatial imbalances

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1 Introduction

Economic activity at the world-wide level has been drifting towards Asia in recent years. In particular, many would agree with the assertion of French (2005) that the growth performance of China and India has pulled "the globe's economic center of gravity decidedly towards Asia". But by how much? And how fast? Although the concept is very popular, there is a surprising lack of formal measurement of the world's economic center of gravity (WECG). One possible reason for this gap in the literature may be that, as the center of gravity of a sphere locates within this object, it makes apparently little sense to report the distance between a real production center (say London) and a point beneath the Earth's surface. However, the change of this distance over time will be informative, as well as the comparison with the distance of another production center (say Auckland). Moreover, although the information value of underground distances may be debatable, surface - or geodesic - distances are widely accepted as an economically relevant concept (and frequently used in the trade gravity literature, e.g. Brun et al (2005)). As the present paper shows that underground and geodesic distances are perfectly correlated, we argue that the concept of a WECG deserves empirical analysis. Indeed, the WECG is an indicator that summarizes the evolution of spatial distribution of economic activities, which is one of the declared objectives of the World Development Report 2009.

The definition of the WECG we propose is directly based on the concept of center of mass (or gravity) in physics, which is the point in space that typifies the system as a whole when it is treated as a particle (e.g. Alonso

and Finn (1980)). The single deviation from the physical definition is that “mass” is replaced in our case by “real production”. Using the center of mass has three important implications. The first one is that the polar coordinates of the WECG encapsulate in a unique point the whole distribution of economic activity around the globe. The second one is that, by relying on a three-dimensional perspective, we can abstract from all the distortions that emerge when the Earth’s surface is represented on a flat map (see Aboufadel and Austin (2006) for a recent discussion in the case of the US mean center of population). The third implication is that the distance between a particular location and the WECG becomes an easy-to-measure alternative to the weighted average distance between this location and all the other markets in the world.

We first present the methodology to estimate the coordinates of the WECG, and also show how it can be used to derive an indicator of spatial imbalance of economic activity across the Earth’s surface. Then we apply these indicators to the 1975-2004 period, comment the results, and conclude.

2 Measuring the WECG

Let us consider the Earth as a perfect sphere with a radius R . Possible production points are distributed uniformly across the surface on a regular lattice. Effective production realized at each point i , $i = 1, \dots, N$, is denoted by q_i , $q_i > 0$, and world production is represented by $Q = \sum_i q_i$. The location of each point is given by the vector of coordinates, $\vec{r}_i = (r_x^i, r_y^i, r_z^i)$, with the origin of the tridimensional space represented by the Earth’s center, which

implies that $(r_x^i)^2 + (r_y^i)^2 + (r_z^i)^2 = R^2$. Then the world's *economic* center of gravity (WECG) is at point E , with a position vector $\overrightarrow{OE} = (r_x^E, r_y^E, r_z^E)$. The following weighted averages define its coordinates:

$$r_x^E = \sum_{i=1}^N \left(\frac{q_i}{Q} \right) r_x^i, \quad r_y^E = \sum_{i=1}^N \left(\frac{q_i}{Q} \right) r_y^i, \quad r_z^E = \sum_{i=1}^N \left(\frac{q_i}{Q} \right) r_z^i. \quad (1)$$

From equation (1) we infer that two sufficient conditions for the WECG to coincide with the origin are that (i) production points are evenly spread across the Earth's surface (geographic homogeneity) and (ii) production is evenly spread across production points (economic homogeneity, $q_i/Q = 1/N$). As neither condition is satisfied in reality, the effective location of point E is a matter of empirical verification.

Incidentally, it is also useful to consider the benchmark case where only condition (ii) is met. This theoretical case of perfect economic homogeneity, but where geographic heterogeneity is present, defines the world's *geographic* center of gravity (WGCG). This point is noted G , and its corresponding position vector \overrightarrow{OG} , has the following coordinates:

$$r_x^G = \frac{1}{N} \sum_{i=1}^N r_x^i, \quad r_y^G = \frac{1}{N} \sum_{i=1}^N r_y^i, \quad r_z^G = \frac{1}{N} \sum_{i=1}^N r_z^i. \quad (2)$$

Thus, by comparing the \overrightarrow{OE} and \overrightarrow{OG} vectors, one can estimate the degree of spatial imbalance that characterizes the location of economic activity across the effective production points. If all locations are economically equivalent, i.e. $q_i/Q = 1/N$, the two vectors perfectly overlap. In all other situations, there is some degree of spatial imbalance, which is reflected by the distance between

the world's economic and geographic gravity centers. Following Zhao et al (2003), we define our indicator of spatial imbalance, δ_G , as the ratio between the effective distance between points E and G , and the maximum distance between actual point G and the antipodes of that point:

$$\delta_G = \frac{\|\overrightarrow{GE}\|}{\|\overrightarrow{OG}\| + R} = \frac{\sqrt{\|\overrightarrow{OG}\|^2 + \|\overrightarrow{OE}\|^2 - 2\|\overrightarrow{OG}\|\|\overrightarrow{OE}\|\cos(\beta)}}{\|\overrightarrow{OG}\| + R} \quad (3)$$

where $\overrightarrow{GE} = \overrightarrow{OE} - \overrightarrow{OG}$ and β is the angle between vectors \overrightarrow{OE} and \overrightarrow{OG} . In other words, δ_G reflects the extent of economic spatial imbalance, expressed as a percentage of the potential maximum, given the location of the WGCG.

Finally, note that point G attributes the same weight to any location while population density varies a lot across production points. Controlling for human population density, a third center of gravity can be estimated. It is named the world's *demographic* center of gravity (WDCG), represented by vector \overrightarrow{OD} , and has the following coordinates:

$$r_x^D = \sum_{i=1}^N \left(\frac{p_i}{P}\right) r_x^i, \quad r_y^D = \sum_{i=1}^N \left(\frac{p_i}{P}\right) r_y^i, \quad r_z^D = \sum_{i=1}^N \left(\frac{p_i}{P}\right) r_z^i \quad (4)$$

where $\frac{p_i}{P}$ is the share of location i in world population ($P = \sum_i p_i$). This provides an alternative benchmark to compare vector \overrightarrow{OE} with. Using formula (3) in which \overrightarrow{OG} has been replaced by \overrightarrow{OD} , one obtains an additional indicator of spatial imbalance. It is denoted by δ_D and presents the same properties as δ_G , but rather than indicating uneven dispersion of economic activity across

production points, it does so across individuals.¹

3 Empirical Results

To make the above framework operational, we need a definition of a “production point” that goes beyond the country level. An ideal candidate would be a square meter, but we have no systematic data on how national production is allocated across each country’s territory, and how this allocation is changing over time.² A reasonable proxy is to take cities, which present easier to access data, are increasingly used in applied studies at the world level (e.g. Antweiler et al, 2001, or Head and Mayer, 2004), have an acceptable degree of geographical coverage and are the main centers of economic activity. Assuming identical GDP per capita between cities of a given country, national production can then be allocated across cities of a given country according to each city’s share in total urban population.

Our sample covers 392 cities with more than one million inhabitants in 80 countries (see table A1 in the Appendix), with a reasonable degree of representativeness whatever the continent (the sample share in total population is systematically larger than 65%, and the corresponding figure for GDP is 85%, see table A2 in the Appendix). The production level is captured by real PPP GDP figures elaborated by the World Bank (2006) and available for

¹Although it is tempting to interpret δ_D as an indicator of income inequality one should remain cautious: it does not satisfy the Pigou-Dalton principle, because it is essentially designed to capture locational imbalances, not inter-individual ones.

²An exception is the data grid of Nordhaus (2006), but it is only available for 1990 and leads, for that year, to the same results as those reported in the present paper (see the robustness exercises below).

the 1975-2004 period. Urban population figures come from Brinkhoff (2006), and are only available for the latest year, so they were extrapolated backward using the aggregate population figures and assuming that the relative size of cities is stable over time for a given country. To control for cyclical variations, population and production figures have been averaged over three-year subperiods. Latitude (λ_i) and longitude (ϕ_i) data are taken from Compare Infobase (2006).³

3.1 Location of the WECG

Our calculations (table 1 reports the polar coordinates of the WECG) suggest that, in the mid 1970s, the WECG (equation (1)) is located beneath the North-Eastern coast of Iceland, at 3600 km from the Earth's center. Over time, it shifts steadily to the North-East and locates at the end of the sample period at the South-East of Spitzbergen, 8% closer to the Earth's center, and after a 1,100 km journey from the inner mantle to the outer core of the Earth (see figure 1 for a representation of the \overrightarrow{OE} vector in the three dimensional space (x, y, z) and figure 2a for the projection of this vector on the Earth's surface). Regarding the other centers of gravity (see figures 1, 2a and 2b), the WDCG is the most eccentric (it remains at a roughly constant 3800 km from the Earth's center) and its projection on the surface shifts to the South (from Southern Kazakhstan to the most Western part of China for a total journey of 280

³The conversion of latitude and longitude into Cartesian coordinates rely on the usual formulas: $r_x^i = R \cos(\lambda_i) \cos(\phi_i)$, $r_y^i = R \cos(\lambda_i) \sin(\phi_i)$, and $r_z^i = R \sin(\lambda_i)$. Similarly, the latitude and longitude of the WECG, i.e. the position of the Earth's surface projection of the \overrightarrow{OG} vector, are obtained by calculating: $\lambda_G = \arcsin(r_z^G / \|\overrightarrow{OG}\|)$ and $\phi_G = \arctan(r_y^G / r_x^G)$. In all calculations, R is given by the radius of the Earth's volume-equivalent perfect sphere (6371 km).

km), while the WGCG (equation (2)) is right beneath St Petersburg, remains unchanged as the cities in the sample do not change, and is the closest to the Earth's center (2900 km).

Insert table 1: Polar coordinates of the world's economic center of gravity

Insert figure 1: Initial and final position of the three world's centers of gravity

Insert figure 2a: Projection of the economic and geographic centers of gravity

Insert figure 2b: Projection of the world's demographic center of gravity

These results are consistent with the fact that a substantial part of world economic production still locates at either side of the North Atlantic, but that the share of Asia has substantially increased in the past decades. By contrast, population has been larger in Asia for a long time, so that the WDCG (equation (4)) clearly locates in this continent. The population share of Africa (and South America to a lesser degree) has increased since 1975, explaining the Southern drift of the WDCG. Overall, this suggests that the distribution of economic activity has become more even worldwide, with regard to both geographical location and individuals. And indeed, as illustrated by figure 3, the two indicators (δ_G and δ_D) point towards a lower degree of spatial economic imbalances over time.

Insert figure 3: Indicators of spatial economic imbalances

Similar calculations have been performed to identify the economic, geographic and demographic centers of gravity at the continent level (see Appen-

dix figure A1). It turns out that all these centers remain virtually unchanged but for two economic centers of gravity: in Asia, where it shifts unsurprisingly to the South-East, and in Africa, where it shifts to the North, mostly in response to the economic stagnation in the central part of the continent. Thus, it appears that the changes in the WDCG reflect mainly composition effects between continents (see bottom lines of table A2), while the changes in the WECG result from the combined influence of both between and within continents variations.⁴

The robustness of these estimates has been tested in a variety of ways (see table A3). Alternative calculations were performed by either extending the sample to those countries that do not report data prior to 1990 (essentially ex Soviet Republics) or by taking into account GDP per capita differences between Chinese provinces. We also used the Nordhaus (2006) grid database for 1990. Our results are basically robust to these changes. An additional benchmark was estimated by considering, as still frequently assumed in the trade literature, that each country is only represented by its capital (or the main economic center). In this particular case, the deviation is larger. The projection of the WECG is still shifting North-East, but at a slower pace, and at lower latitudes than those obtained by the alternative samples.

⁴The corresponding centers of gravity, along with all the other ones of the paper, are available from the author's web-page (www.hec.unil.ch/nmathys) and can be displayed using the freely downloadable Google-Earth software.

3.2 Distances to the WECG

Going a step further, we can compute, for each city, its distance to the WECG. Strictly speaking, the distances we refer to in this paper are different from geodesic distances (i.e. between two points on the Earth’s surface). However, the distinction between the two concepts turns out to be inconsequential because, as shown formally in the appendix, the direct distance to the WECG is a positive and monotone function of the (geodesic) distance to the projection of the WECG on the Earth’s surface. Moreover, there is a close association between the distance to the WECG and the distance-to-markets remoteness indicator frequently used in the trade gravity literature (see Polak, 1996)). In our sample, and whatever the time period, the rank correlation between the two is systematically higher than 0.99. This suggests that the direct distance to the WECG or the geodesic distance to its surface projection may be used as convenient alternatives to the more data-demanding remoteness indicator.

Appendix table A4 lists the average distance to the WECG for the 15 most “central” and the 15 most “remote” cities. The most central city is Stockholm, followed by other North European, mainly British, cities. The most remote cities are located in the Southern hemisphere. The most distant city is Auckland in New Zealand followed by Australian and South-American cities, plus Port Elizabeth in South Africa. Table A5 reports cities with the most extreme rates of change in the distance to the WECG over the sample period. The largest decreases in remoteness are overwhelmingly observed for Chinese cities, even if the overall “winner” is a Russian city (Krasnojarsk). At the other extreme, the biggest losers are Western European cities (plus Casablanca and Rabat in

Morocco), although they remain on average close to the WECG in absolute terms.

Appendix table A6 reports distances between the WECG and the projection on the Earth's surface of the economic center of gravity of each country. As could be expected, Northern Europe countries exhibit the lowest distance (slightly above 3000 km) while the most distant countries (more than 8000 km) are those that are relatively close to the Southern pole. Over time, the largest losers are Ireland and Spain, the largest gainers are China and South Korea while the situation hardly changes at all for South Africa and Sudan.⁵

Although informative, these distances are difficult to compare across continents, as each continent locates on average at a different distance from point *E*. This comparability problem is solved in table 2 by presenting in a first step the average distance between the continent's cities and either the WECG (point *E*) or the WGCG (point *G*). This allows for a ranking of the continents by increasing distance, showing that on average an Oceanian city is 2.5 (2.2) times further away from the economic (geographic) center of gravity than a European one. In a second step, we abstract from these intercontinental differences by computing the *distance ratio* of each individual city, i.e. the ratio between the distance to point *E* and the distance to point *G*. If the distance ratio is higher than 1, it means that the city suffers from a *relative locational disadvantage*, because it is further away from the economic than the geographic center of gravity. Conversely, if the distance ratio is smaller than 1, this reflects

⁵For those interested in using this variable in gravity equations for instance, an excel file with the distances by country and period is available from the author's web-page.

a relative locational *advantage*.⁶

Table 2: Distances and distance ratios to the world’s economic center of gravity

The analysis of average distance ratios at the continent level reveals that initially Europe and the two Americas benefit from a locational advantage. However, this advantage erodes strongly over time, while the initial disadvantage of Asia and Oceania shrinks. In other words, the continents that started with a disadvantage “gain”, while those that started with an advantage “lose” over time. The only continent that stands apart from this convergence trend is Africa: it starts with a locational disadvantage of 1.04 and ends up with the highest average distance ratio, at 1.11, while all other continents are below 1.05. Figures at the city level exhibit a similar convergence pattern but with stronger variations. The remaining lines of table 2 identify the largest “gain-ers” and “losers” by continent. The overall loser is Dublin (Ireland), with an increase of 24%, while Krasnojarsk (Russia) exhibits the largest gain (a 17% decrease).⁷ Note that all cities in Oceania actually gain (i.e. experience a decrease in the distance ratio), while all cities in North and South America lose.

⁶By multiplying the distance ratio by the average continental distance to the WGCG one obtains an approximation of the absolute distance between the city and the WECG.

⁷As the world’s geographic center of gravity does not change location over time, the percentage changes in table 2 are identical to those of table A5 for the cities that appear in both tables.

4 Conclusions

In short, to those who could argue that Asia is already the world's economic center this paper's answer is: "not yet". Based on data from the largest world cities, our calculations suggest that the world's economic center of gravity still locates somewhere beneath Northern Europe, but it has been steadily moving towards Asia in the last decades. As the demographic center of gravity is clearly in Asia, this movement accounts for a more homogeneous dispersion of economic activity around the globe. At the city level, the sharpest contrast is between (both South and North) American cities, whose initial locational advantage has been fading away, while the disadvantage of Asian and Oceanian cities is reduced. At the continental level, the only continent that stands apart from this global convergence is Africa: on average, the locational disadvantage of its cities increases over the sample period.

These results could probably be refined by considering more cities or taking into account the dispersion of economic activity within each country. This may lead to corrections at the continent or city level, although our own attempts suggest that the overall picture would remain unchanged. Thus, the projection of the world's economic center of gravity at the Earth's surface that emerges from the present analysis may be used as a universal yardstick for estimating the distance between a particular location and world markets.

A final comment regarding the future. If growth were to continue to follow the same pattern it followed in the recent past, the world's economic center of gravity should indeed, at some stage, cross the Asian border somewhere.

According to our calculations (and regardless of the period on which the extrapolation is based), the place would be the coast of the Yamal peninsula (Russia), in the year 2030.

Appendix: geodesic and direct distances

Let us consider that point P_i , on the Earth's surface, is characterized by coordinates r_x^i, r_y^i, r_z^i , and point E , the WECG, by coordinates r_x^E, r_y^E, r_z^E , with the origin at the Earth's center. Define α as the angle (expressed in radians) between vectors $\overrightarrow{OP_i}$ and \overrightarrow{OE} , and point \tilde{E} as the projection of point E on the Earth's surface. The vectors' norms are denoted $\|\overrightarrow{OP_i}\| = \|\overrightarrow{OE}\| = R$, $\|\overrightarrow{O\tilde{E}}\| = W < R$. Define \tilde{d}_i as the *geodesic* distance between point P_i and point \tilde{E} , while d_i is the *direct* distance between point P_i and point E . Elementary geometry in the plane defined by vectors $\overrightarrow{OP_i}$ and \overrightarrow{OE} leads to the following expressions:

$$\tilde{d}_i = \alpha R \quad (5)$$

$$d_i^2 = (R \sin \alpha)^2 + (R \cos \alpha - W)^2 \quad (6)$$

The usual trigonometric identities ($\cos^2 \alpha + \sin^2 \alpha = 1$, $(1 - \cos \alpha) = 2 \sin^2(\alpha/2)$) allow to rewrite equation (6) as $d_i^2 = (R - W)^2 + 4WR \sin^2(\alpha/2)$, from which it follows that:

$$\tilde{d}_i = 2R \arcsin \left[\frac{1}{2} \sqrt{\frac{d_i^2 - (R - W)^2}{RW}} \right] \quad (7)$$

which is a monotonous and positive function of d_i across its interval of variation $([0; R])$.

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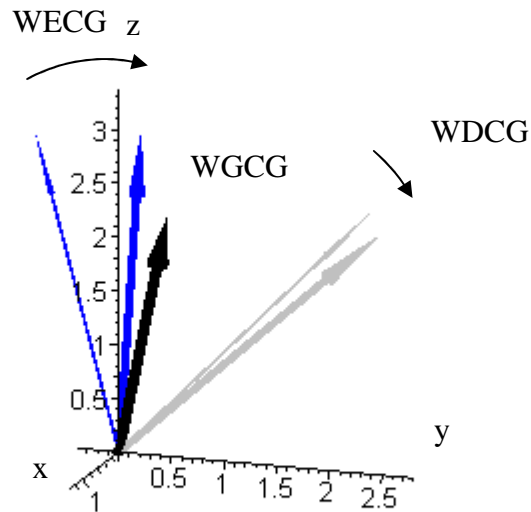
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Figures and Tables

"Is the World's Economic Center of Gravity Already in Asia?"

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Figure 1: Initial and Final Position of the three World's Centers of Gravity



Notes:
 10^3 km on axis.
 WECCG: World's Economic Center of Gravity
 WGCG: World's Geographic Center of Gravity
 WDCG: World's Demographic Center of Gravity

Table 1: Polar Coordinates of World's Economic Center of Gravity

Period	Latitude (°)	Longitude (°)	Distance to Earth Center in km
1975-77	67.0 N	13.5 W	3'605
1978-80	67.7 N	14.3 W	3'566
1981-83	68.8 N	9.9 W	3'521
1984-86	70.2 N	8.6 W	3'498
1987-89	71.5 N	4.4 W	3'467
1990-92	72.9 N	3.0 E	3'441
1993-95	74.5 N	8.9 E	3'347
1996-98	75.3 N	16.6 E	3'301
1999-01	75.4 N	21.3 E	3'316
2002-04	75.2 N	32.7 E	3'317

Figure 2a: Projection of the World's Economic and Geographic Center of Gravity (WECG and WGCG)

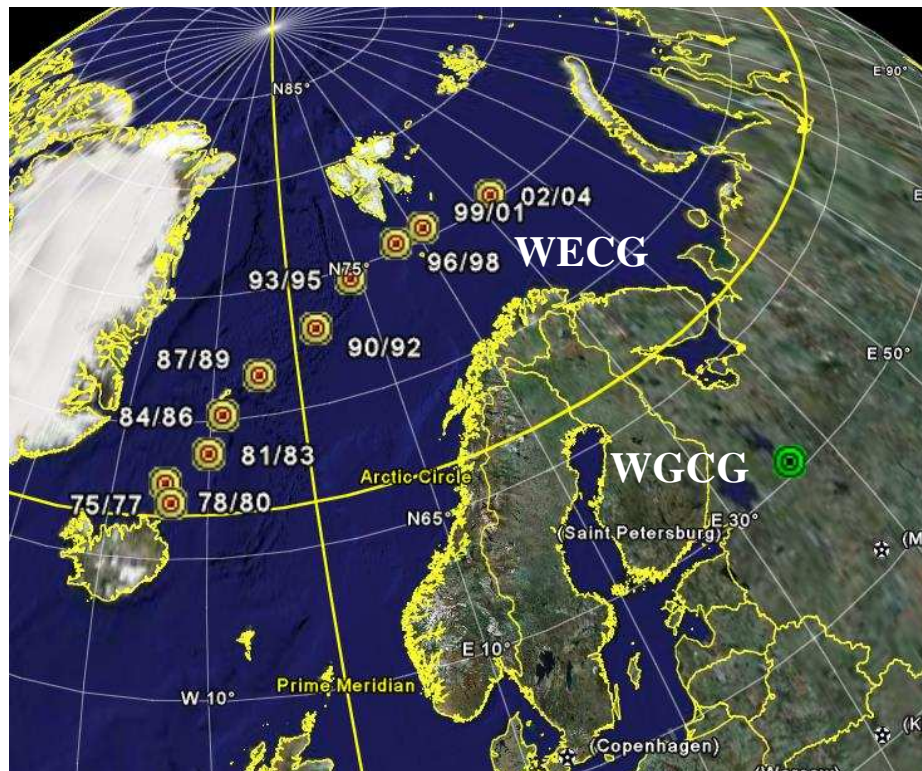


Figure 2b: Projection of the World's Demographic Center of Gravity (WDCG)

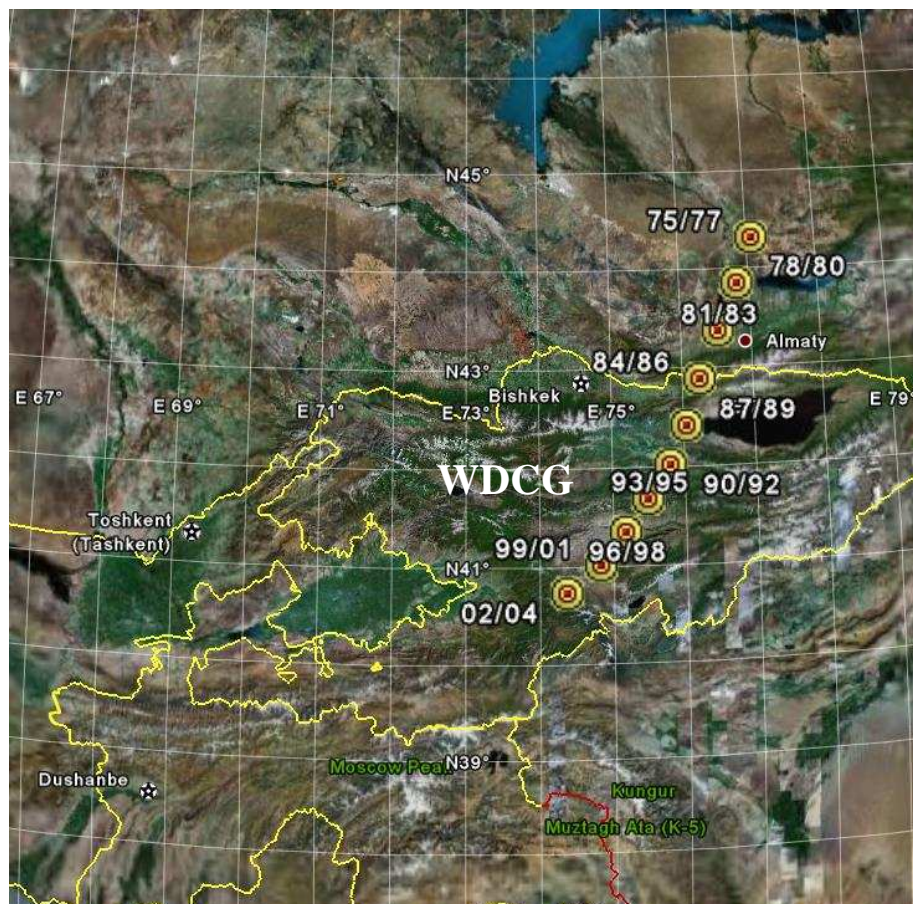


Figure 3: Economic Homogeneity Indicators

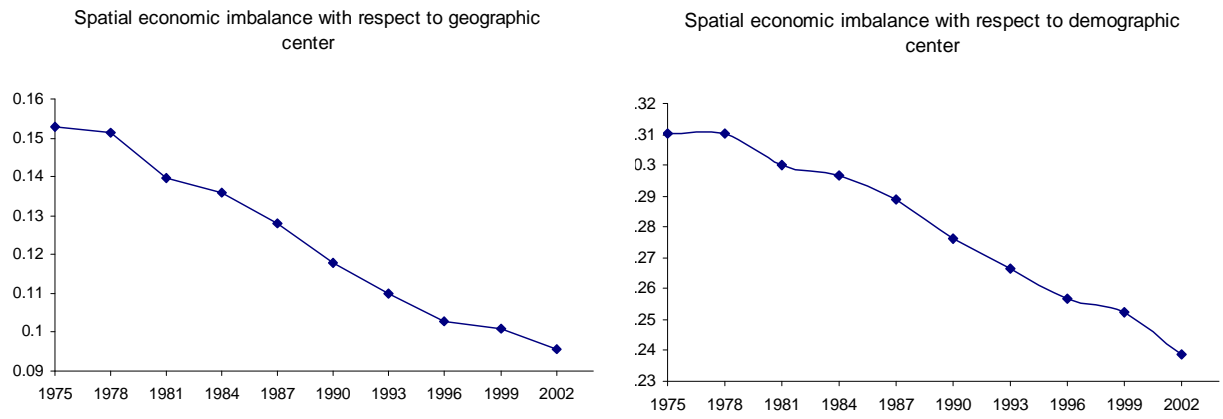


Table 2: Distances and Distance Ratios* to the World's Centers of Gravity

	Europe	Asia	Africa	North America	South America	Oceania
Continental Average						
◦ Distance to WGCG (in 10 ³ km)	3.79	5.00	5.54	6.33	7.54	8.51
◦ Average Distance to WECG (in 10 ³ km)	3.55	5.61	6.00	5.44	7.34	9.17
◦ Initial Distance Ratio	0.87	1.19	1.04	0.82	0.93	1.12
◦ Percentage Change 1975-2004 (%)	16.29	-12.21	7.16	11.38	9.58	-7.32
Largest Continental Loser	Dublin (Ireland)	Izmir (Turkey)	Casablanca (Morocco)	Boston (USA)	Caracas (Venezuela)	Auckland (New Zealand)
◦ Initial Distance Ratio	0.78	1.06	0.87	0.76	0.86	1.08
◦ Percentage Change 1975-2004 (%)	23.86	3.55	20.38	20.07	13.93	-5.68
Largest Continental Winner	Tbilisi (Georgia)	Krasnojarsk (Russia)	Antananarivo (Madagascar)	Albany (USA)	Santiago (Chile)	Perth (Australia)
◦ Initial Distance Ratio	1.15	1.14	1.18	0.86	0.98	1.16
◦ Percentage Change 1975-2004 (%)	-5.16	-17.06	-3.49	2.95	5.24	-8.22

Note:

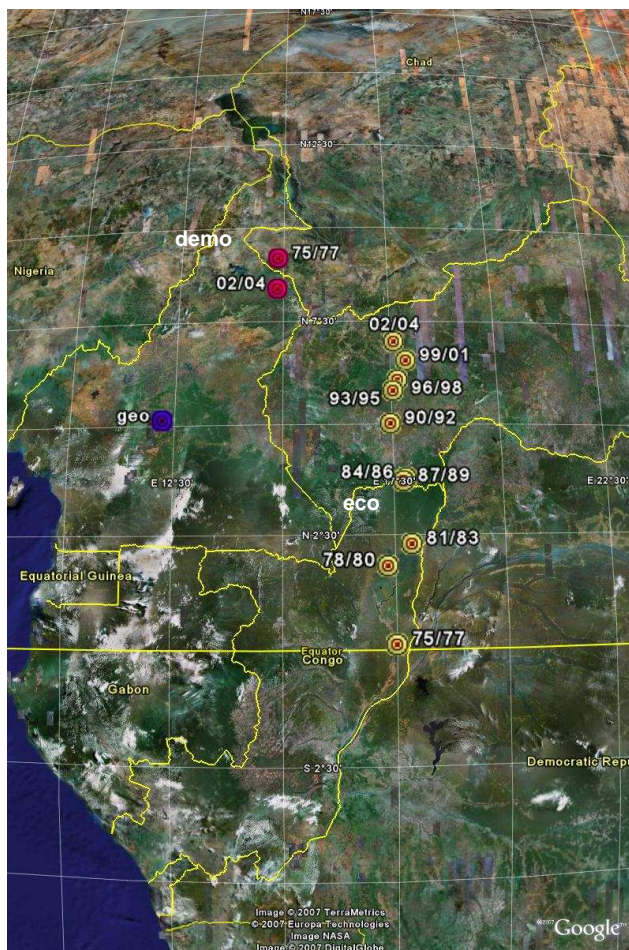
WGCG: World's Geographic Center of Gravity, WECG: World's Economic Center of Gravity

* Distance Ratio = Distance to WECG/ Distance to WGCG

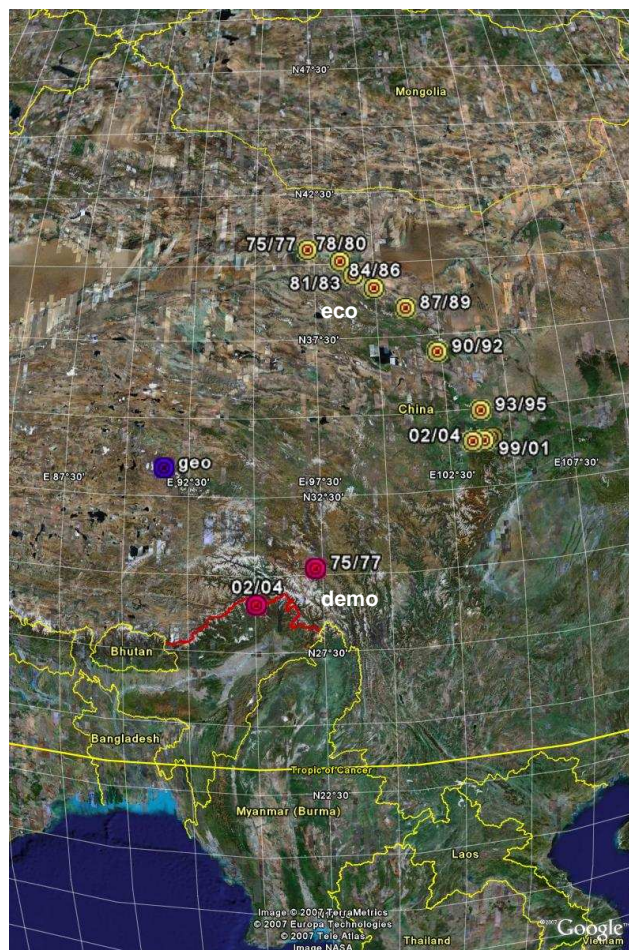
Appendices Figures and Tables

Figure A1: Economic, Geographic and Demographic Centers at the continental level

(a) Africa



(b) Asia



(c) Europe

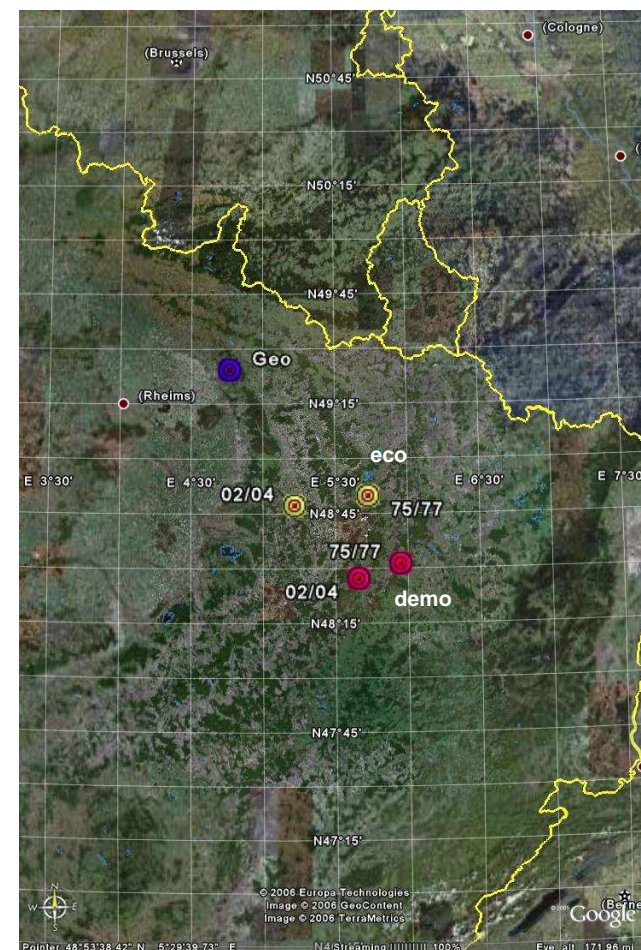
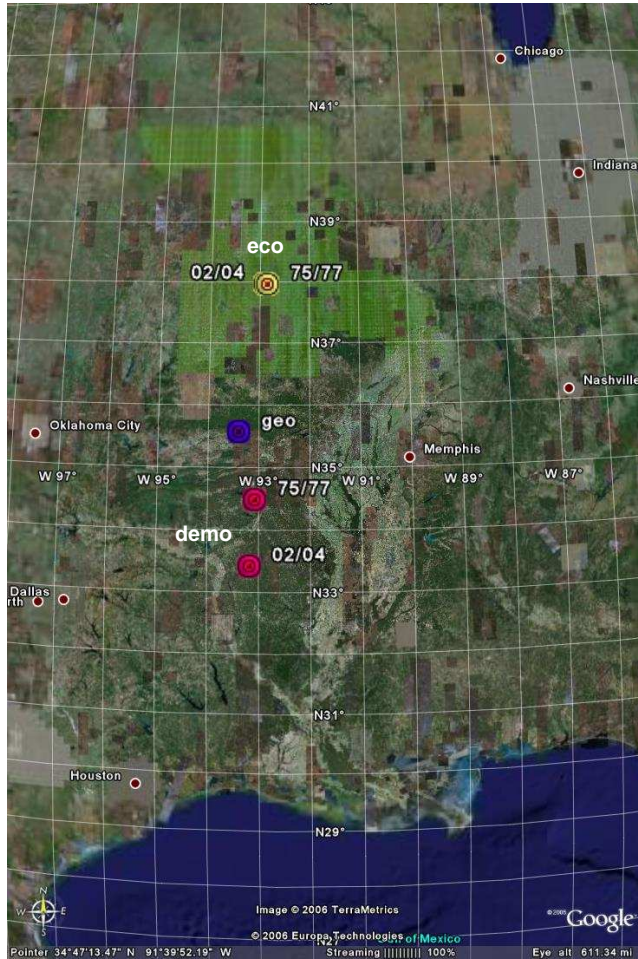
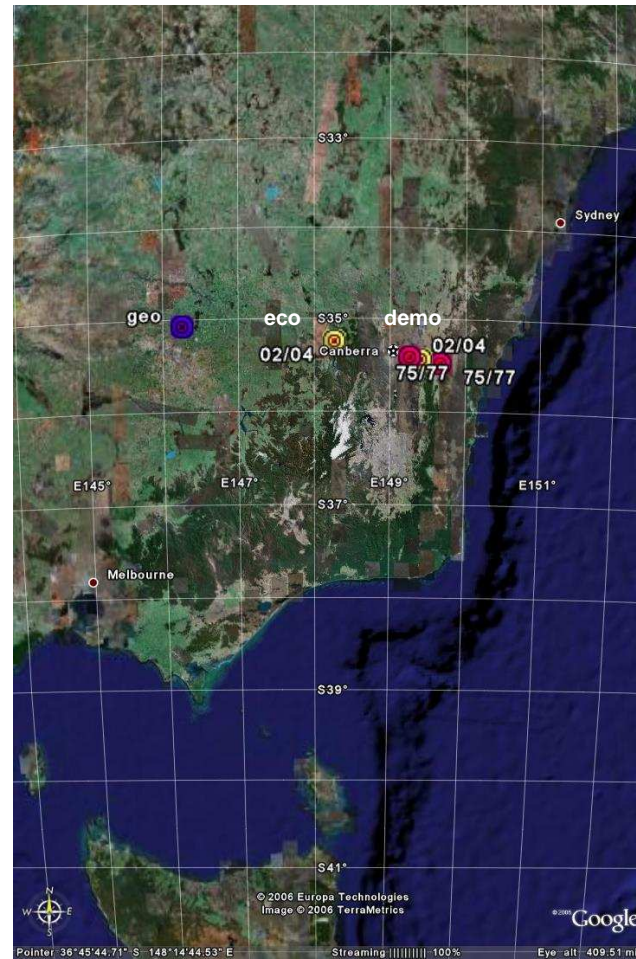


Figure A1: Economic, Geographic and Demographic Centers at the continental level (end)

(d) North America



(e) Oceania



(f) South America

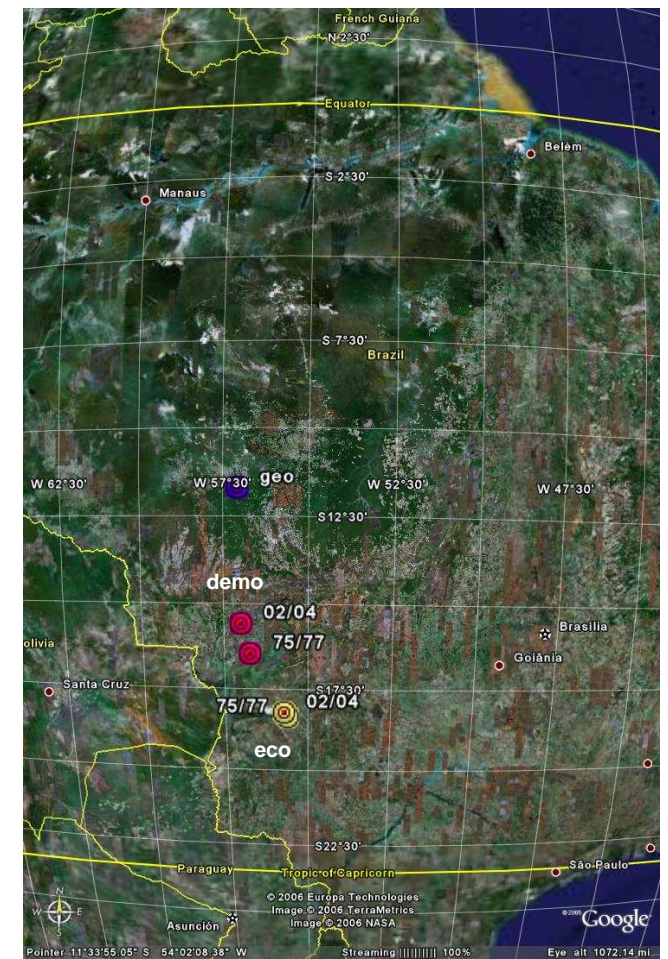


Table A1: Sample Countries (Number of countries in parenthesis)

Africa (20)	Asia (22)	Europe (17)	North America (11)	South America (10)
Algeria	Bengladesh	Austria	Canada	Argentina
Burkina Faso	Burma	Belgium	Costa Rica	Bolivia
Cameroon	China	Denmark	Dominican Rep.	Brazil
Congo, Rep.	India	Finland	El Salvador	Chile
Congo, Dem. Rep.	Indonesia	France	Guatemala	Colombia
Egypt	Iran	Georgia	Haiti	Ecuador
Ghana	Israel	Germany	Mexico	Paraguay
Ivory Coast	Japan	Greece	Nicaragua	Peru
Kenya	Jordan	Hungary	Panama	Uruguay
Madagascar	Korea (South)	Ireland	Puerto Rico	Venezuela
Mali	Malaysia	Italy	United States	
Morocco	Nepal	Netherlands		Oceania (2)
Nigeria	Pakistan	Portugal		Australia
Senegal	Philippines	Spain		New Zealand
Sierra Leone	Russian Fed.	Sweden		
South Africa	Saudi Arabia	Switzerland		
Sudan	Singapore	United Kingdom		
Tunisia	Sri Lanka			
Zambia	Syria			
Zimbabwe	Thailand			
	Turkey			
	United Arab Emirates			

Table A2: Sample Structure and Representativity

		World	Africa	South America	North America	Asia	Europe	Oceania
Number of Large Cities		392	37	43	77	182	47	6
Number of Sample Countries		82	20	10	11	22	17	2
Sample Share in Total Population (%)*		83	67.87	99.60	94.43	92.39	66.24	77.81
Sample Share in Total GDP (%)*		95	86.98	99.86	99.00	98.30	91.24	96.65
Share in Sample Population (%)	1975/77	100	8.09	6.15	9.21	65.67	10.39	0.48
	2002/04	100	10.63	6.70	8.72	66.07	7.44	0.44
Share in Sample GDP (%)	1975/77	100	3.87	7.05	28.82	29.14	29.69	1.43
	2002/04	100	3.34	5.66	26.76	40.59	22.29	1.36

Note:

* Average across the sample period, total figures obtained by considering all countries of the geographic entity.

Table A3: Polar Coordinates of World's Economic Center of Gravity: alternative calculations

Variable	Estimation	1975-77	1978-80	1981-83	1984-86	1987-89	1990-92	1993-95	1996-98	1999-01	2002-04
Latitude (°)	Baseline	66.98 N	67.71 N	68.75 N	70.15 N	71.51 N	72.91 N	74.51 N	75.26 N	75.41 N	75.23 N
	Enlarged Sample						71.52 N	73.04 N	73.74 N	73.86 N	73.53 N
	Chinese Province Data	67.05 N	67.80 N	68.83 N	70.26 N	71.63 N	73.03 N	74.68 N	75.47 N	75.64 N	75.47 N
	Nordhaus Data						70.00 N				
	One City Per Country	61.82 N	62.43 N	63.47 N	64.65 N	65.96 N	67.48 N	69.07 N	70.06 N	70.46 N	71.03 N
Longitude (°)	Baseline	13.51 W	14.25 W	9.93 W	8.57 W	4.37 W	2.98 E	8.86 E	16.63 E	21.25 E	32.68 E
	Enlarged Sample						7.72 E	12.84 E	19.63 E	23.74 E	33.79 E
	Chinese Province Data	13.05 W	13.83 W	9.50 W	8.16 W	3.92 W	3.51 E	9.41 E	17.28 E	22.01 E	33.66 E
	Nordhaus Data						10.48 E				
	One City Per Country	11.94 W	12.48 W	9.43 W	8.44 W	5.55 W	0.48 W	3.07 E	7.87 E	10.75 E	18.45 E
Distance to Earth Center, in km	Baseline	3'604.94	3'565.64	3'521.14	3'498.23	3'466.75	3'441.19	3'347.17	3'301.03	3'316.33	3'317.14
	Enlarged Sample						3'500.82	3'400.55	3'348.79	3'361.84	3'366.65
	Chinese Province Data	3'608.41	3'568.50	3'523.98	3'500.43	3'468.92	3'443.59	3'348.44	3'301.77	3'317.01	3'317.56
	Nordhaus Data						3'560.20				
	One City Per Country	3865.03	3822.16	3770.04	3754.57	3722.51	3691.46	3600.97	3557.69	3579.96	3582.00

Notes:

The enlarged sample includes additionally Angola, Armenia, Belarus, Bulgaria, Ethiopia, Guinea, Kazakhstan, Kyrgyz Republic, Poland, Romania, Tajikistan, Tanzania, Uganda, Ukraine, Vietnam, Yemen, Rep.

Chinese province GDP data from the China Statistical Yearbook (2003) are additionally exploited.

The Nordhaus (2006) data is only available for 1990.

One City Per Country: for each country, only the main city is considered.

Table A4: Top 15 Cities in Average Distance

		City	Country	Average Distance (in 10³ km)
Smallest Distance	1	Stockholm	Sweden	3.19
	2	Helsinki	Finland	3.22
	3	Glasgow	Great Britain	3.25
	4	St.Petersburg	Russia	3.26
	5	Newcastle upon Tyne	Great Britain	3.28
	6	Copenhagen	Denmark	3.28
	7	Leeds	Great Britain	3.32
	8	Manchester	Great Britain	3.33
	9	Liverpool	Great Britain	3.33
	10	Sheffield	Great Britain	3.33
	11	Dublin	Ireland	3.34
	12	Hamburg	Germany	3.34
	13	Birmingham	Great Britain	3.37
	14	Amsterdam	Netherlands	3.38
	15	The Hague	Netherlands	3.38
Largest Distance	1	Auckland	New Zealand	9.38
	2	Melbourne	Australia	9.29
	3	Sydney	Australia	9.23
	4	Adelaide	Australia	9.18
	5	Brisbane	Australia	9.06
	6	Perth	Australia	8.90
	7	Santiago	Chile	8.48
	8	Valparaíso	Chile	8.47
	9	Buenos Aires	Argentina	8.40
	10	Montevideo	Uruguay	8.39
	11	Rosario	Argentina	8.35
	12	Cordoba	Argentina	8.33
	13	Porto Alegre	Brazil	8.14
	14	Port Elizabeth	South Africa	8.10
	15	Sao Luis	Brazil	8.10

Table A5: Top 15 Cities according to Distance Growth Rate

		City	Country	Change (%), 1975-2004
Gainers	1	Krasnojarsk	Russia	-17.06
	2	Qiqihar	China	-16.99
	3	Huhehot	China	-16.96
	4	Daqing	China	-16.95
	5	Baotou	China	-16.94
	6	Datong	China	-16.87
	7	Beijing	China	-16.79
	8	Harbin	China	-16.75
	9	Changchun	China	-16.73
	10	Tientsin	China	-16.70
	11	Shenyang	China	-16.67
	12	Taiyuan	China	-16.67
	13	Shijiazhuang	China	-16.66
	14	Fushun	China	-16.65
	15	Anshan	China	-16.64
Losers	1	Dublin	Ireland	23.86
	2	Porto	Portugal	23.22
	3	Lisbon	Portugal	22.67
	4	Glasgow	Great Britain	22.59
	5	Liverpool	Great Britain	22.24
	6	Manchester	Great Britain	21.82
	7	Birmingham	Great Britain	21.73
	8	Leeds	Great Britain	21.44
	9	Sheffield	Great Britain	21.43
	10	Newcastle upon Tyne	Great Britain	21.34
	11	Sevilla	Spain	20.97
	12	Madrid	Spain	20.86
	13	London	Great Britain	20.78
	14	Casablanca	Morocco	20.38
	15	Rabat	Morocco	20.23

Table A6: Distance to WECG (in 10³ km) by Country

Country	Period		Country	Period	
	1975-77	2001-04		1975-77	2001-04
Algeria	3.81	4.45	Jordan	4.62	4.57
Argentina	8.19	8.65	Kenya	6.56	6.46
Australia	9.55	8.83	Madagascar	7.68	7.41
Austria	3.42	3.78	Malaysia	7.70	6.77
Bangladesh	6.39	5.49	Mali	5.18	5.89
Belgium	3.16	3.73	Mexico	6.11	6.60
Bolivia	7.45	8.07	Morocco	3.91	4.69
Brazil	7.29	7.93	Nepal	6.03	5.18
Burkina Faso	5.23	5.85	Netherlands	3.12	3.68
Cameroon	5.86	6.23	New Zealand	9.65	9.10
Canada	4.36	5.00	Nicaragua	6.29	6.94
Chile	8.29	8.73	Nigeria	5.57	6.06
China	6.33	5.32	Pakistan	5.56	4.92
Colombia	6.39	7.12	Panama	6.31	7.02
Congo (Dem. Rep.)	6.51	6.72	Paraguay	7.74	8.31
Congo (Rep.)	6.40	6.66	Peru	7.39	7.98
Costa Rica	6.35	7.02	Philippines	7.48	6.46
Côte d'Ivoire	5.66	6.26	Portugal	3.59	4.41
Denmark	3.10	3.49	Russia	3.64	3.43
Dominican Republic	5.54	6.39	Saudi Arabia	5.26	5.05
Ecuador	6.87	7.52	Senegal	5.06	5.88
Egypt	4.60	4.66	Sierra Leone	5.44	6.18
El Salvador	6.27	6.89	Singapore	7.80	6.87
Finland	3.15	3.30	South Africa	7.87	7.87
France	3.26	3.86	South Korea	6.27	5.27
Georgia	4.29	4.07	Spain	3.60	4.44
Germany	3.21	3.69	Sri Lanka	7.04	6.28
Ghana	5.64	6.20	Sudan	5.50	5.50
GBR and N. Ireland	3.06	3.70	Sweden	3.07	3.34
Greece	4.04	4.25	Switzerland	3.35	3.86
Guatemala	6.25	6.85	Syria	4.48	4.41
Haiti	5.60	6.42	Thailand	7.12	6.16
Hungary	3.49	3.80	Tunisia	3.88	4.38
India	6.19	5.42	Turkey	4.05	4.13
Indonesia	8.16	7.24	USA	4.94	5.54
Iran	4.81	4.45	United Arab Emirates	5.45	5.01
Ireland	3.01	3.72	Uruguay	8.18	8.65
Israel	4.58	4.56	Venezuela	5.48	6.38
Italy	3.57	4.04	Zambia	7.21	7.22
Japan	6.47	5.49	Zimbabwe	7.37	7.34