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Is the world's economic centre of gravity already in Asia?

Jean-Marie Grether* and Nicole A Mathys*,**

*Institute of Economic Research, University of Neuchatel, Pierre-à-Mazel 7, CH-2000 Neuchâtel, Switzerland

**Swiss Federal Office of Energy, CH-3003 Bern, Switzerland

Email: nicole.mathys@gmail.com

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This paper proposes a novel and simple measure of the world's economic centre of gravity. Over the recent decades, this centre has shifted towards Asia, but is still located in Europe.

Key words: *location of economic activity, centre of gravity*

Introduction

Although the concept is very popular in the globalisation debate, there is a surprising lack of formal measurement of the world's economic centre of gravity (WECG) in the empirical literature. Probably the main reason for this discrepancy is that the centre of gravity of a sphere locates within this object, and it makes intuitively little sense to report the *underground* distance between a real production centre (say London) and a point beneath the Earth's surface. This contrasts with the *geodesic* (or surface) distances, which are used by economists, notably in the trade gravity literature (e.g. Brun *et al.* 2005). However, by projecting a gravity centre on the Earth's surface, as is commonly done by geographers (e.g. Aboufadel and Austin 2006), it is simple to convert an underground into a geodesic distance. Moreover, as the present paper shows, underground and geodesic distances are in fact perfectly correlated. Thus, it can be argued that the concept of a WECG deserves consideration, and this paper illustrates which type of empirical patterns it reveals.

Measuring the WECG

The proposed definition of the WECG is directly based on the concept of centre 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 this case by 'real production'. Let us then consider the Earth as a perfect sphere of radius R. Possible production points are distributed uniformly across the surface on a regular lattice. Effective production realised at each point i, $i = 1, \ldots N$, is denoted by q_i, $q_i > 0$, and world production is represented by $Q = \sum_{i=1}^{N} q_i$. 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 centre, which implies that $(r_x^i)^2 + (r_y^i)^2 + (r_z^i)^2 = R^2$. Then the world's economic centre of gravity (WECG) is at point E, with a position vector $\overrightarrow{OE} = (r_x^E, r_y^E, r_z^E)$, and the following weighted averages define its coordinates:

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

Two additional world centres can be defined by replacing in equation (1) the production shares $\left(\frac{q_i}{Q}\right)$ by alternative weights. Using population shares, one obtains the world's demographic centre of gravity (WDCG, point D), while using identical shares ($1/N$), one obtains the world's geographic centre of gravity (WGCG, point G).

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Empirical results

To apply the above framework to real data, a definition of a 'production point' is needed that goes beyond the country level. An ideal candidate would be a square metre, but due to data constraints cities represent a reasonable proxy. As production per city is not available for all countries, population data are used: assuming identical GDP per capita between cities of a given country, national production can be allocated across cities of a given country according to each city's share in total urban population. The empirical sample covers 392 cities with more than 1 million inhabitants in 80 countries.[1]

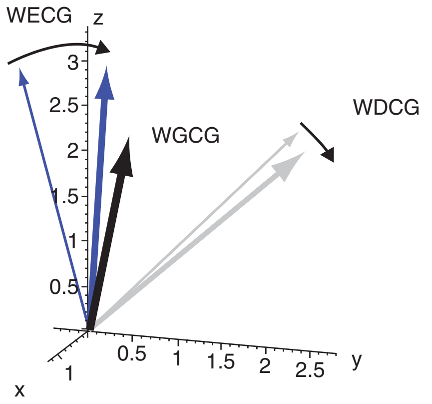
Location of the WECG

Calculations (Table 1 reports the polar coordinates) suggest that in the mid 1970s the WECG is located beneath the north-eastern coast of Iceland, 3600 km from the Earth's centre. 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 per cent closer to the Earth's centre, and after a 1100 km journey from the inner mantle to the outer core of the Earth (see Figure 1 for a representation of the $\overrightarrow{OE}$ vector and Figure 2 for the projection of this vector on the Earth's surface).[2] Regarding the other centres of gravity, the WDCG is the most eccentric (it remains at a roughly constant 3800 km from the Earth's centre) 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 km), while the WGCG is right beneath St Petersburg and remains unchanged as the cities in the sample do not change and is the closest to the Earth's centre (2900 km).

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 recent decades. By contrast, population has been larger in Asia for a long time, so that the WDCG clearly locates in this

Table 1 Polar coordinates of the WECG

Period	Latitude (°)	Longitude (°)	Distance to Earth centre (km)
1975–77	67.0 N	13.5 W	3605
1978–80	67.7 N	14.3 W	3566
1981–83	68.8 N	9.9 W	3521
1984–86	70.2 N	8.6 W	3498
1987–89	71.5 N	4.4 W	3467
1990–92	72.9 N	3.0 E	3441
1993–95	74.5 N	8.9 E	3347
1996–98	75.3 N	16.6 E	3301
1999–01	75.4 N	21.3 E	3316
2002–04	75.2 N	32.7 E	3317



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

Figure 1 Initial and final positions of the three world's centres of gravity

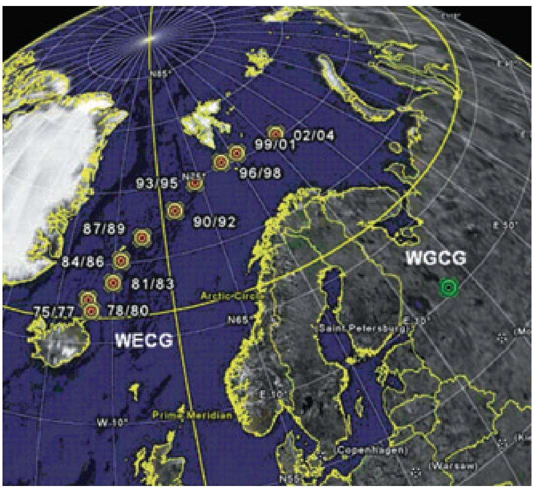


Figure 2 Projections of the WECG and WGCG

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Table 2 Distances to the WECG (continental averages)

	Europe	Asia	Africa	North America	South America	Oceania
Distance to WGCG (10^3 km)	3.79	5.00	5.54	6.33	7.54	8.51
Distance to WECG (10^3 km)	3.55	5.61	6.00	5.44	7.34	9.17
Initial distance ratio[a]	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

Notes: WGCG: world's geographic centre of gravity, WECG: world's economic centre of gravity. [a] Distance ratio = distance to WECG/distance to WGCG

continent. The population share of Africa has increased since 1975, explaining the southern drift of the WDCG.

Regarding robustness, the location of the WECG has been analysed in a variety of ways. Firstly, the GDP-by-city technique was replaced by the 1990 data grid of Nordhaus (2006), which reports gross output at a 1-degree longitude by 1-degree latitude resolution at a global scale. This more comprehensive data set, which is however only available for 1990, leads to an estimate of the WECG for that particular year which is close to the one reported above: slightly more to the South (by 3-degrees latitude), to the East (by 7-degrees longitude), and closer to the Earth's surface (by 120 km). Secondly, the above results were compared to those obtained either by enlarging the sample with 16 additional countries after 1990 (mostly from the former USSR and Africa), or by taking into account GDP per capita differences across Chinese provinces. These additional exercises hardly affected results for 1990, and kept unchanged the general trajectory of the WECG over time.

Distances to the WECG

Going a step further, one can compute for each city its distance to the WECG. Strictly speaking, the distances which are referred to here 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 it can be shown, 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.[3] 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 this paper's sample 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.

Although informative, these distances are difficult to compare across continents, as each continent locates on average at a different distance from point *G*. In other words, even if production was evenly spread across all world cities, an average Oceanian city would appear more distant from the WECG than a European one simply because Oceania is geographically remote vis-à-vis other continents *E*. This comparability problem is solved in Table 2. First, continents are ranked by increasing average distance from the WGCG, showing indeed that on average an Oceanian city is 2.2 times further away from the geographic centre of gravity than a European one. Second, one can 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 and vice versa. In the case of Oceania, the average initial distance ratio is 1.12, suggesting that even after controlling for the fact that this is a geographically remote continent, the average Oceanian city is still relatively remote from the world economic centre of gravity (i.e. it is more distant from the WECG than would be implied by a uniform distribution of economic activity across all cities).

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. 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.

A final word of caution is in order regarding the interpretation of distances to the WECG. It is generally recognised in the trade literature that simple geodesic distance in terms of kilometres is an imperfect proxy for the 'true' economic distance in terms of transport costs (e.g. Hummels 2001). However, there is no universally accepted methodology to correct for this problem, and data requirements (in terms of geographical obstacles, road densities or trade barriers) become rapidly huge. That is why, in spite of their limitations, geodesic distances are still very widely used in the trade gravity literature. Moreover, in the case of this paper, it may be argued that geographical characteristics and trade barriers were sufficiently stable over time so that the benchmark trend reported in this paper would be left essentially unaffected by further refinements regarding distance measurement.

Conclusions

To those who argue that Asia is already the world's economic centre this paper's answer is: 'not yet'. Calculations suggest that the WECG still locates somewhere beneath Northern Europe, but it has been steadily moving towards Asia in recent decades. The projection of the WECG at the Earth's surface 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 WECG should indeed, at some stage, cross the Asian border somewhere. Extrapolating recent trends shows that the place would be the coast of the Yamal peninsula (Russia), in 2030.

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Notes

1 Data sources, detailed results and alternative working hypothesis are presented in an extended working paper version available as Grether and Mathys (2008).

2 The core is the innermost part of the Earth, while the mantle is the layer just above the core, the separation between the two locating at 3450 km from the Earth's centre. Note that the length of the OE vector is a consequence of the asymmetry of the distribution of production sites on the Earth's surface (influenced itself by the asymmetric distribution of land); it may also be interpreted as a gauge of the precision of the projection (for a given error of measurement in the location of point E, the error of the projection on the Earth's surface is smaller the larger the length of vector OE).

3 The direct distance is given by $d_i = \sqrt{(R\sin\alpha)^2 + (R\cos\alpha - W)^2}$ and the geodesic distance by $\tilde{d}_i = \alpha R$, where α is the angle between $\overrightarrow{OP_i}$ and $\overrightarrow{OE}$, W is the length of $\overrightarrow{OE_i}$, and P_i is a particular point on the Earth's surface. Using trigonometric identities one obtains $\tilde{d}_i = 2R\arcsin\left[\frac{1}{2}\sqrt{\frac{d_i^2 - (R-W)^2}{RW}}\right]$.

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