The Global Economy's Shifting Centre of Gravity

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Abstract

This article describes the dynamics of the global economy's centre of gravity, the average location of economic activity across geographies on Earth. The calculations here take into account all the GDP produced on this planet. The article finds that in 1980 the global economy's centre of gravity was mid-Atlantic. By 2008, from the continuing rise of China and the rest of East Asia, that centre of gravity had drifted to a location east of Helsinki and Bucharest. Extrapolating growth in almost 700 locations across Earth, this article projects the world's economic centre of gravity to locate by 2050 literally between India and China. Observed from Earth's surface, that economic centre of gravity will shift from its 1980 location 9,300 km or 1.5 times the radius of the planet.

Policy Implications

- If soft power mirrors but lags economic power, then the source for global and political influence will be similarly gradually shifting east over the next 50–100 years.
- Policy formulation for the entire global economy, and global governance more generally, will no longer be the domain of the last century's rich countries but instead will require more inclusive engagement of the east.
- Many global policy questions will remain the same, e.g. promoting growth in the world economy, but others might change in character, e.g. appropriate political and military intervention.

This article presents the dynamics of the global economy's centre of gravity. Studying such dynamics forms part of more general ongoing research on the world's shifting distribution of economic activity (Quah, 2010). By economic centre of gravity, I mean the average location of the planet's economic activity measured by GDP generated across nearly 700 identifiable locations on the Earth's surface. The calculations in this article take into account the entirety of GDP produced on this planet.

Grether and Mathys (2009) have previously estimated this same concept of the world economic centre of gravity, focusing on large urban agglomerations. Brinkhoff (2009) has presented related data on the planet's urban areas. The work here builds on Grether and Mathys' important contribution in two ways. First, I extend the observations to cover GDP in all of the world's economies, constructing in each national economy a spatial conditional average to stand in for the economic activity located outside the large urban agglomerations. Second, I formulate a cylindrical projection method to represent the dynamics of the global economy's centre of gravity, taking into account that that centre of gravity is typically located in the interior of the planet.

I report below that the world's economic centre of gravity (WECG) located in 1980 at a point in the middle of the Atlantic Ocean. By 2008, however, that centre of gravity had drifted to a location at about the same longitude as Izmir and Minsk, and thus east of Helsinki and Bucharest. Of course, this change occurred not due to the emergence of Turkey or Belarus, but instead from the continuing rise of China and the rest of East Asia.

Extrapolating growth in the 700 locations across Earth, the world's economic centre of gravity is projected by 2050 to locate, literally, between India and China. Observed from Earth's surface, that economic centre of gravity will shift away from its 1980 location a distance of 9,300 km or 1.5 times the radius of the planet.

Beyond this substantive conclusion, this article contributes a methodological innovation. The study of earth projections by geographers (e.g. Snyder, 1993) has,

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historically, dealt with the problem of accurately representing on a two-dimensional map locations and shapes that rest on the surface of a curved three-dimensional sphere. The subject matter is extensive but the critical result is that no perfect representation exists (Gauss's Theorema Egregium). No one representation can be necessarily more accurate than all the others in every characteristic of interest. This study seeks to represent on to the same two-dimensional map not just the usual points on the Earth's surface but locations and trajectories that penetrate the surface of that three-dimensional sphere and tunnel into the sphere's interior. Therefore, the mathematical problem is at least as intricate as that for the standard Earth projection, and the same impossibility result implies that no representation can be ideal in every possible way. Instead, what this article does is propose and apply a projection (or distance-minimising) technique to describe on a two-dimensional map the world's economic centre of gravity.

Aside from the representation problem, the equations for calculating a spatial weighted average – as for calculating any weighted average – are of course invariant and unique, and thus in this article are necessarily the same equations exactly as appear in Grether and Mathys (2009). In this direction, the current article only furthers that line of analysis initiated in Grether and Mathys (2009) by adding a set of observations to pick up the global economy located *outside* urban agglomerations: the Grether and Mathys study considered only that part of the global economy within urban agglomerations. I follow Grether and Mathys in ascribing a constant per capita income across urban agglomerations within a national economy. However, I also hypothesise a positive but lower per capita income in the areas outside those urban agglomerations. Grether and Mathys, by contrast, impute zero incomes for those (rural) areas.

While it might be tempting as a result to say that what I do here improves or makes more precise the estimation of the world's economic centre of gravity, I think it would be more useful to consider my estimates as simply being different, in substance, from those in Grether and Mathys. Since what we seek to estimate is unknown and unmodelled it is not possible to say which of our estimates is more precise or more reasonable. Comparing their table 1 and their figure 1 with Figure 2 and its table in this article cannot determine whose estimates should be preferred. Reassuringly, however, our substantive conclusions remain the same although of course the details will differ.

Finally, the world's economic centre of gravity should not be confused with a concept of *clustering* of world economic activity. To see this difference, suppose for instance that the world only had two locations, say Beijing and New York, and these two places shared equal amounts of economic activity. Then the world's economic centre of gravity would be exactly halfway between Beijing and New York. And that centre would show exactly zero economic activity. In this example, there are two clusters – one in Beijing, the other in New York – but only one centre, precisely midway between them. Indeed, in general, as the centre is the average, there can only ever be one centre. Each of the different concepts contains useful information. Therefore, the WECG given here holds interest because it shows tendencies – the sharp eastward drift of economic activity as Beijing grows faster than New York – not because that central location is where everyone should seek their economic fortunes. For the latter, the appropriate concept is clustering, not the centre of gravity. Indeed, in the example I have just given, as long as Beijing and New York remain equal, a business would wish to locate as far as possible from the centre of gravity.

1. Motivation

Typical cross-country studies of income dynamics deduce parameters from the cross-sectional variation to help assess the causes of economic growth. Such analyses hypothesise a representative or average economy in whose properties the researcher is interested. This study, by contrast, takes its principal concern to be the dynamic behaviour of the entire spatial distribution of economic activity. The mean of that spatial distribution of income across the planet is the global economy's centre of gravity. I focus on that mean because it is a convenient and tractable representation of that distribution, not because of any inherent interest in the representative or average economy.

Why do this? There are two large sets of reasons, both concerning the dynamics of the distribution of incomes across economies. A first is that understanding the changing income distribution across economies gives insight into the future evolution of global inequality more generally (e.g. Held and Kaya, 2006; Milanovic, 2005; Quah, 2003) and thus of global justice and the state of humanity.

A second set of reasons is that such understanding provides critical input into another wide-ranging group of questions across the social sciences. Among these are questions surrounding the rise of the BRICs (Goldman Sachs Global Economics Group, 2007); the emergence of Asia (Mahbubani, 2008); the relative decline of the world's established global powers (Cox, 2007); the evolution of the world's reserve currency and, more broadly, change in the global monetary system (Chinn and Frankel, 2008); and the evolving global distribution of soft power (Nye, 2004). Such issues can be addressed only by modelling the entire cross-country distribution of economic and political activity, not by analysing a hypothetical representative economy.

2. Calculations

I took, to begin, national GDP figures adjusted for purchasing power parity (World Bank, 2010) augmented with data for Taipei China (Asian Development Bank, 2008). This provided 210 data points per year. Then I used Google Earth to determine the geographical locations of every urban agglomeration on the planet having 2009 populations exceeding 1 million (Brinkhoff, 2009 and Grether and Mathys, 2009 have previously also discussed and presented data on those locations). This gave 483 urban agglomerations on Earth. Some nation economies have no such agglomeration, others many: for example, China had 79; India, 48; the US, 54.

To add to this collection, using Google Earth again but now together with uniform spatial averaging, I located the point average across geographical extent in each of the 210 nation economies. This gave for each nation economy a single point proxying for the rural (non-urban) geography. Altogether, these 483 urban agglomerations and 210 rural proxies provided 693 identifiable locations on Earth.

Following Grether and Mathys (2009) I allocated national income across locations so that all urban agglomerations within a nation economy had equal per capita income. I assigned per capita income in the remainder of the nation economy to be 10 per cent lower than in the urban agglomerations. This last step diverges from Grether and Mathys (2009), who omitted all geographies outside urban agglomerations. Put another way, Grether and Mathys (2009) applied a rural discount of 100 per cent. I experimented with varying this rural discount between 0 per cent and 40 per cent with almost imperceptible change in the end results.

A more extensive study might attempt to model rural–urban income dynamics more carefully, and analyse changes in spatial locations as cities emerge or vanish. I do not pursue such extensions here.

To summarise, I took 693 locations to represent the spatial distribution of all the economic activity on Earth. Tracking incomes in these locations over time gives a representation of the spatial distribution dynamics of global economic activity. At any given point in time, calculating the three-dimensional weighted average across the 693 locations yields the WECG. Take the approximation that Earth ε is exactly spherical with radius R and that a location for economic activity is a point on the three-dimensional Earth's surface. Written in Cartesian coordinates,

$$\zeta = (\zeta_x, \zeta_y, \zeta_z) \text{ with } |\zeta| = (\zeta_x^2 + \zeta_y^2 + \zeta_z^2)^{\frac{1}{2}} = R.$$

(In future, with ongoing scientific progress, locations for economic activity might be off the Earth's surface – whether above or below – so that the last equality would then no longer hold. However, nothing essential changes in the calculations.) Denote the collection of all urban agglomerations and rural proxies:

$$\{\zeta^{(i)} : i = 1, 2, \ldots, N\}.$$

For W the measure of economic activity of interest, here income, the world's economic centre of gravity is that point $\bar{\zeta} \in \varepsilon$ such that

$$\bar{\zeta} = \sum_{i=1}^{N} W^{(i)} \zeta^{(i)} / \sum_{i=1}^{N} W^{(i)}$$

Typically, $|\bar{\zeta}| < R$, that is, this centre of gravity lies within the Earth's volume, not on its surface.

When $\zeta = (\zeta_x, \zeta_y, \zeta_z)$ is an urban agglomeration that rests on the planet's surface and has latitude φ and longitude λ measured in radians, the Cartesian coordinates relate to latitude and longitude by:

$$\zeta_x = R \cos\varphi \cos\lambda$$

$$\zeta_y = R \cos\varphi \sin\lambda$$

$$\zeta_z = R \sin\varphi.$$

The easiest way to understand this calculation is to project a point ζ on to the equatorial plane and then to decompose that projection along x and y coordinates in that plane.

The latitude and longitude of any $\zeta = (\zeta_x, \zeta_y, \zeta_z)$, not necessarily on the planet's surface, can be recovered as:

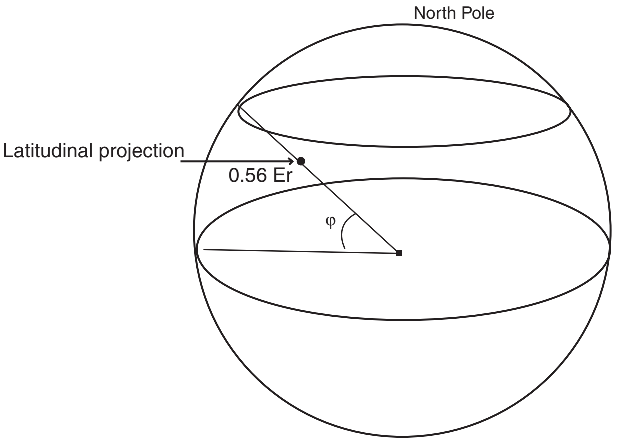
$$\varphi = \sin^{-1}(\zeta_z/|\zeta|) \text{ and } \lambda = \tan^{-1}(\zeta_y/\zeta_x) \quad (1)$$

with its distance from the physical centre of the planet given by $|\zeta| = (\zeta_x^2 + \zeta_y^2 + \zeta_z^2)^{1/2}$.

Given the data used in this article, the resulting WECG turns out to be well beneath the surface of the planet. Tracking the dynamics of such subterranean locations is not straightforward.

On a two-dimensional map any point on the Earth's surface bears a unique configuration relative to the usual landmarks of coastlines, cities and mountains. That property fails, however, for points beneath the surface of the three-dimensional planet. To see this, suppose that some sequence of points inside the planetary sphere has an east-to-west trajectory when viewed from one perspective. But when viewed from the other side of the planet that same sequence will instead traverse west to east. Since any given perspective is arbitrary in three-dimensional space, without further justification for fixing a viewing position, no discussion of the centre of gravity moving east (or west) can draw a compelling conclusion.

Figure 1. Calculating the cylindrical projection.



Note: When the WECG is 0.56 Earth's radius from the physical centre, its latitude φ makes it appear much further north than it actually is. The cylindrical projection realigns perspective appropriately and, by virtue of being a (distance-minimising) projection, locates the closest point on the planet's surface to the WECG.

Related to this ambiguity, latitudinal and longitudinal information for subterranean points can be visually misleading. For instance, a point close to the Earth's physical centre but only a little distance north will have a relatively large latitudinal measure. This last will make that location appear much closer to the North Pole when it is compared with other locations the same distance north of the equatorial plane but which themselves rest on the planet's surface (Figure 1). These anomalies arise from deeper technical difficulties in projecting the three-dimensional Earth on to a two-dimensional flat map. In contrast, previous mapping analyses (Snyder, 1993) have only ever considered projecting points on the Earth's surface, not locations deep underground.

To minimise this visual misperception and ambiguity, the maps I present will depict, when indicated, a WECG mapped on to the Earth's surface by projecting from the planet's north–south axis to the cylindrical surface tangent at the planet's equator. Again, see Figure 1. It might seem that such cylindrical projection necessarily exaggerates movement in the WECG. A counterexample, however, confirms it does not. Suppose the shifting distribution of global economic activity pulls the WECG further into the planet's interior but directly toward the north–south axis: then the WECG's cylindrical projection registers zero variation whereas, in reality, the physical movement can be considerable.

3. Results

In 1980 the WECG located 24 degrees West and 66 degrees North, but 2,800 kilometres (almost half Earth's radius) beneath the surface of the Atlantic Ocean. Along the east–west axis, this location is between Iceland and Brazil. Intuitively, the 1980 WECG sat between North America and Western Europe because most of the world's economic activity then occurred in just those two geographies.

At 66 degrees North relative to the equatorial plane, the WECG might seem to be as far north as Iceland. However, measured along the north–south axis, the WECG – because it is so deep beneath the planet's surface – turns out to be only 3,200 kilometres north of the equator, approximately the same distance north as Austin, Texas, Tel Aviv or Shanghai.

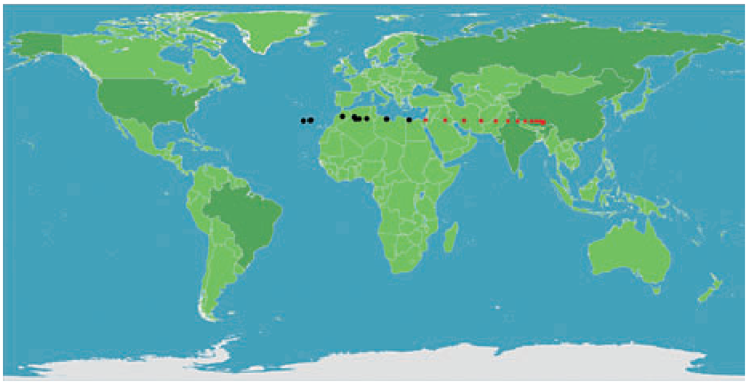
This account just given suggests a way to describe the dynamics of the WECG while preserving visual intuition, as described briefly at the end of the previous section. Project the WECG onto the Earth's surface by locating both the WECG and its surface projection on the straight line that minimises the distance between Earth's north–south axis and a cylinder tangent to the equator. Roughly speaking, the projection is that point on the Earth's surface that someone would be looking at when they fix their eyes on the north–south axis while encircling Earth on the equatorial-tangent cylinder, and the WECG just comes into view. (And that observer is hypothesised to be able to look only orthogonally from the surface of the cylinder.)

Figure 2 shows the shifting WECG at three-year intervals between 1980 and 2007 in the historical sample, and then extrapolated forwards to 2049. I calculated the WECG beyond 2008 by fitting exponential trends individually for each of the nearly 700 geographical locations, and then re-estimating the WECG each year between 2009 and 2049. Along with Figure 2, I also provide a table containing longitude, latitude and radial distance of each of these WECGs, as well as the latitude of the cylindrical projection on to the planet's surface: these are the numbers used in the figure.

To emphasise again, in this construction, Figure 2 shows the sequence of WECGs not from a single fixed perspective. Instead each point in Figure 2 is from one element in a sequence of perspectives that track the WECGs as the latter traverse their trajectory.

By 2008 the WECG had drifted to a location 27 degrees East and 74 degrees North (surface projected, 31 degrees North). Viewed from the tangent cylinder, 2008's WECG appeared just south of Izmir, Turkey, on the same longitude as Minsk and Johannesburg. Over the quarter of a century since 1980, the WECG has travelled 1,135 km (18 per cent of Earth's radius) through three-dimensional space. Its surface projection – that distance perceived in Figure 2 – moved 4,800 km or 75 per cent of Earth's radius across the surface of the planet from its 1980 location in the middle of the Atlantic Ocean.

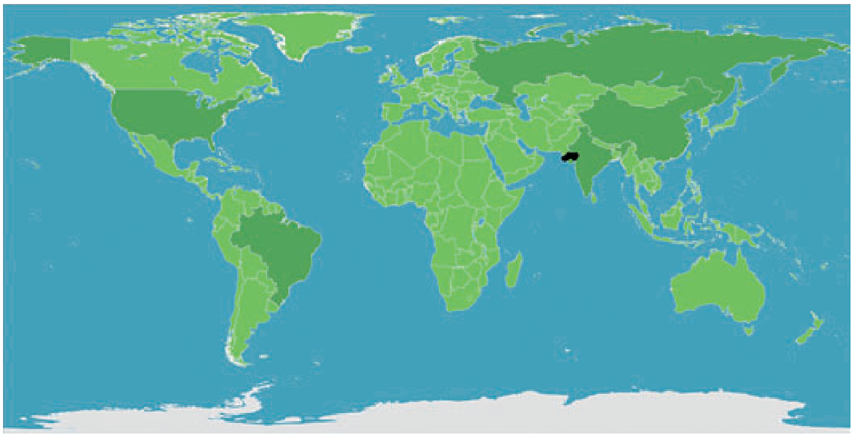
Figure 2. The world's economic centre of gravity, 1980–2007 (black) and extrapolated (in red, reduced size, italicised in table), at three-year intervals.



Year	Latitude (degrees)	Projected Latitude (degrees)	Longitude (degrees)	Radial Distance (Earth's radius)
1980	66	31	–24	0.56
1983	68	31	–21	0.56
1986	69	31	–21	0.55
1989	72	33	–6	0.57
1992	73	32	0	0.56
1995	73	32	3	0.55
1998	73	32	1	0.55
2001	74	32	6	0.55
2004	74	32	16	0.55
2007	73	31	27	0.54
2010	*73*	*31*	*35*	*0.54*
2013	*72*	*31*	*44*	*0.54*
2016	*71*	*31*	*53*	*0.54*
2019	*69*	*31*	*62*	*0.55*
2022	*66*	*31*	*69*	*0.56*
2025	*64*	*31*	*75*	*0.57*
2028	*61*	*31*	*79*	*0.58*
2031	*58*	*31*	*83*	*0.60*
2034	*55*	*31*	*86*	*0.62*
2037	*52*	*31*	*88*	*0.64*
2040	*50*	*31*	*90*	*0.66*
2043	*48*	*30*	*91*	*0.69*
2046	*46*	*30*	*92*	*0.71*
2049	*44*	*30*	*92*	*0.72*

Source: Author's calculations.

Figure 3. Flat world's economic centre of gravity, 1980–2007.



Source: Author's calculations.
Note: Karachi is the nearest large city to either 2007's or 1980's WECG.

Some readers have suggested that the WECG's eastward movement is simply an artefact of a Euro-Asia-centric perspective. Had we viewed this same sequence of points from the Pacific Ocean instead, the traversal would be westward. However, locating the map's perspective in the Pacific Ocean would not trace out the cylindrical projection – which, recall, is defined to be a distance-minimising mapping.

Another striking feature of Figure 2 is how the WECG seems to move so rigidly along a given latitude, that is, visually horizontally in the map. Does this imply that the north–south divide will remain invariant, so that even as the south grows, so too does the north?

To address this point, look at the table following Figure 2. That shows the actual latitude of the WECG in its second column. Notice that that latitude declines from 66 degrees North to 44 degrees North by 2049. This might seem to imply that the south, like the east, is actually gaining considerable relative economic strength.

However, at the same time, the radial distance of the WECG from the centre of the earth has risen, from 0.56 to 0.72 of the planet's radius. Therefore, the WECG is percolating up to the surface of the planet. These two tendencies imply that when viewed from the surface of the planet, there is little north–south movement.

To visualise this, consider drawing a circle around the Earth at about 30 degrees North on the planet's surface. Then slice that circle right into the interior of the planet. What Figure 2 shows is that the WECG remains on that slice even though drifting toward the planet's surface. I interpret this to mean that the north–south divide remains constant, and thus Figure 2 correctly illustrates the reality.

By 2049 the surface-projected WECG is forecast to approach a limit point around 92 degrees East and 30 degrees North. That location is no large city precisely but surrounding it are Urumqi, China, Kolkata, India, Dacca and Chittagong, Bangladesh and Mandalay, Myanmar. In this extrapolation, by 2050 the WECG will shift in three-dimensional space 4,250 km, or two-thirds of the Earth's radius. Its surface projection will move 9,300 km, or 1.5 times Earth's radius eastward across the surface of the planet.

The forecast limit point is close to what the WECG would be if the world were flat, that is, when per capita incomes equalise everywhere. (This uses the same evocative phrasing but is obviously a drastic simplification of themes developed in Friedman (2006).) Such a flat-world centre of gravity is arithmetically identical to a spatial average using population rather than income as weights for each location: Grether and Mathys (2009) presented exactly the same calculation and referred to it as the demographic centre of gravity. While the calculation is, obviously, the same, their and my interpretations differ for this location. In my description, I consider this flat-world centre of gravity to hold interest because it describes a possible future when per capita incomes equalise. For Grether and Mathys (2009) the interest lies in how this location is the geographical centre of the world's population. Figure 3 shows the flat world's WECG in 2009 located 68 degrees East and 38 degrees North (surface projected, 23 degrees North), close by Karachi. The WECG under this definition obviously does evolve through time but the variation – whether historical or extrapolated (not shown) – is minimal relative to that in Figure 2.

Conclusions

This article has documented the dynamics of the world's economic centre of gravity. The results show that such a centre of gravity began in the mid-Atlantic in 1980, reflecting how most of the world's economic activity then occurred in either North America or Western Europe.

Since 1980, however, the historical evidence has implied a profound eastward shift in economic activity. In 2008 the world's economic centre of gravity had moved close to Izmir, thus having been pulled 4,800 km (75 per cent of the Earth's radius) eastward across the surface of the planet. Extrapolating to 2050, the global economy's centre of gravity will continue to shift east to lie between India and China. Measured on the planet's surface this will be a shift since 1980 of 9,300 km, or 1.5 times the radius of the Earth.

Note

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