MARITIME AFFAIRS: THE JOURNAL OF THE NATIONAL
MARITIME FOUNDATION OF INDIA
2025, VOL 21 NO 1

EINSTEIN, MEANDERING OF RIVERS AND BUSINESS CYCLES

Dr Vishwapati Trivedi

ABSTRACT

This paper dwells in the broad domain of Econophysics. Calling attention to the established theories of why rivers meander, starting from Einstein in 1926 to the well-developed rules of meandering, the paper draws the attention of the reader to its parallels in the field of economics, specifically the building up of business cycles and their sinuosity. The Paper hopes that more studies in this direction are conducted in the future.

Keywords: River Meandering, Einstein, Helical Flow, Sinuosity, Self-Organised Criticality, Business Cycles, Econophysics

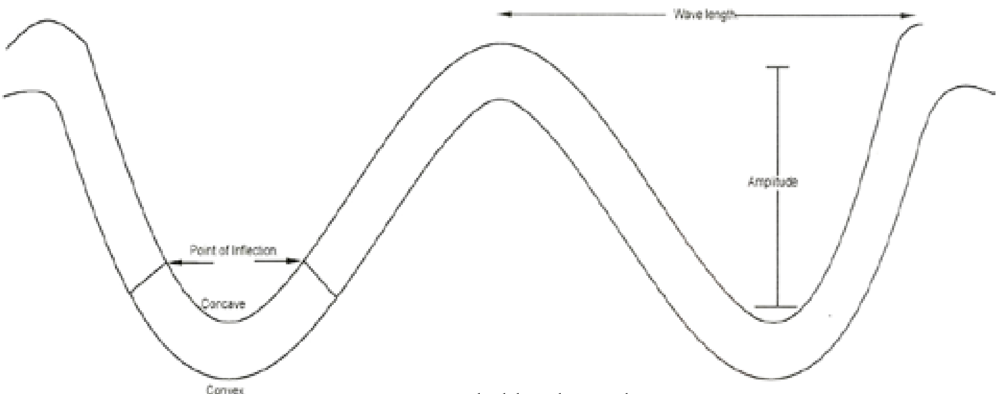
Einstein, in 1926, developed a theory in his famous "thought experiments" style on why rivers meander by observing the tea leaves in a flat-bottomed cup. It is believed that, prior to Einstein, in 1876, James Thomson worked on the helical flow of rivers, but Einstein placed the entire concept within his characteristically simple rigour, including explanations of how the length of the meander is determined and how meanders move as the river flows downstream.

Einstein first published his paper in the German periodical, *Die Naturwissenschaften* in 1926. According to Einstein, as rivers flow, the angular velocity of rotation at the banks of the river is less due to friction than at other places near the centre. The difference in the two velocities gives rise to secondary circular currents, perpendicular to the primary flow. This was explained with reference to the stirring of tea leaves in a teacup, where the leaves gather in the centre. A similar effect, as described above, operates in riverine flows, and the sand grains collect away from the outer bank. Another perspective involves the operation of centrifugal and centripetal forces. Centrifugal forces are stronger on the upper part than the lower part, due to greater exposure to the bank compared to the bottom of the river. Combined with circular motion, this creates a helical flow and, just as the tea leaves settle at the centre of the cup, sand accumulates at the inner bank and forms what are called point bars. Einstein's teacup theory explained the formation of curves and bends in rivers, that is, the meandering of rivers. In India, the name of the ancient river in Ahmedabad (Gujarat), called 'Sabarmati', originated from Sa-"bramathi" (meaning 'wandering' in Sanskrit). The word 'Meander' also derived from a river, the Menderes in Asia Minor, which was known for its circuitous route.

Some might argue that there is nothing remarkable in the physics of riverine flows—a view which is justified to an extent. Water always flows downhill. Due to certain irregular surfaces, the otherwise straightforward route becomes disturbed, generating dimensional forms that ultimately result in curves and turns. However, there is order in this chaos, grounded both in scientific principles, as described above, and in observations recorded by scientific researchers and field surveyors.

This phenomenon can be explained scientifically through six key concepts for understanding the sinuosity of meandering rivers: concave bend, convex bend, points of inflexion, wavelength, radius of curvature, and amplitude.

Figure 1.



Source: Provided by the author

The outer side is known as the convex, while the inner side is the concave. The area between the two bends is called the point of inflexion; amplitude is defined as the distance between the normal flow path and the path altered due to meandering. Wavelength refers to the distance between two bends, and the radius is that of the circle the bend would describe.

As noted above, some potamologists (river study experts) have identified certain observable characteristics. Leopold Luna, Chief Hydrologist of the USGS (United

States Geological Survey), observed that rivers display distinctly marked behaviour and concluded that the wavelength of a bend is about ten times the width and about five times the radius. This implies that the wider the river, the greater the wavelength (for a given radius). From an aerial perspective, meandering rivers typically exhibit a consistent pattern.

Luna also derived that not only the creation, but also the shape of a meander has a design, albeit trigonometric, behind it. He called it a sine-generated curve. He demonstrated successfully that the distance travelled on a river would have a relationship with the direction you are moving in. In brief, for the enthusiasts, if the angle is Ω, and the distance is d, then the relationship will be:

$$\Omega = K.\ \sin\ (d\theta)$$

Over the years, the sinuosity of river behaviour has inspired various studies into the reasons behind river meandering and its underlying physics. Janet Hooke[1] has examined the inherent instability in river meandering, providing a framework for analysis that spans from stability to chaos. Her work principally engages with the idea of self-organised criticality formulated by Bak[2], essentially postulating that, when systems reach a critical state, a minor event can start a chain reaction that can impact the system in many different ways and quantities. Bak supported these conclusions with reference to avalanche behaviour in sand piles, and noted that self-organisation ultimately leads back to general equilibrium.

RELATIONSHIP OF RIVER MEANDER BEHAVIOUR TO BUSINESS CYCLES

This part of the paper relates to "econophysics", defined by Wikipedia as

> *"an interdisciplinary research field, applying theories and methods originally developed by physicists in order to solve problems in economics, usually those involving uncertainty or stochastic processes and nonlinear dynamics."*

In this tradition, a striking relationship has been discovered between business cycle theories in economic systems and the theories that explain the meandering behaviour of rivers. Business cycle theories also start with cycles around a trend. They then discuss the kinds of trends—whether stochastic, deterministic or linear—as well as the existence of segments, which potamologists call trajectories or 'attractors' within the phase space of the rate of meander. Fundamentally, as happens in a river meander, the energies and resistances that exist or are generated within the system govern the entire planform behaviour. It is important, and interesting, to understand that the behaviour is so greatly determined by the laws of physics. This lends credence to the proposition that a business cycle is also a matter of physical conditionality, whether caused by actions of monetary policy (comparable to the flow of water), or by the morphology of the terrain (comparable to the interactions of labour, capital and entrepreneurship).

In economics, two principal types of cycles are recognised: the short-term business cycle (most commonly discussed), and the longer cycles with wavelengths of 15–20 years (Kuznets cycles) or even longer, 40–60 years (Kondratieff cycles). This remains the subject of ongoing debate, as increasing volumes of data accumulate in diverse formats and over varying time frames.

Economists have also tried to distance themselves from the system behaviours in natural sciences, postulating that economic science distinguishes itself because of the existence of positive feedback loops. As a result of the existence of these so-called positive feedback loops, now the economists have come to believe that the earlier theories of economic cycles, which largely concluded that these cycles are mostly linear, does not hold water. The theories of river behaviour have also similarly concluded (as explained above) that the larger waves/amplitudes are made of smaller, triggered-off activities, due to 'attracters.' But the larger wavelengths are explained more appropriately by the self-organising behaviour. This is also reflected in economic theories addressing the behaviour, wavelengths, and amplitude of economic cycles.[3] According to these models, initially, the individual firms acquire capacity, which is inherently oscillatory due to the variety of self-reinforcing factors such as the interactions with other firms, households and governments. This creates an amplitude, possibly destabilising it. Within this, there are divergent oscillations, but essentially limited by external and definitive factors such as capacity utilisations, etc. and causing smaller oscillations within the big waves. One of the important factors here is the rising credit during the upturn, either demand driven or supply driven by monetisation of the fiscal deficit by the Governments. These are likened to flows in the river, where, driven by high flows in the monsoons, the curvatures are created, going by the Einstein principle, explained above. But these are limited by dry seasons and the geo-morphological constraints, likened to the physical constraints on capacity utilisations.

The above theory of the sinuosity of rivers and its physics can be very well used to study the behaviour of business cycles faced by the nations and the world. The distinction is that the rivers meander and be observed and measured for curvature and wavelength with some certainty, while in an economy, the existence of invisible particles, mostly of expectations and rational human minds driven by 'animal spirits,' reduces the capacity to be more certain.

ENDNOTES

1 Janel Hooke, "River Meander Behaviour and Instability: A Framework for Analysis." *Transactions of the Institute of British Geographers*, 28, No. 2 (2003).

2 Per Bak, Chao Tang, and Kurt Wiesenfeld, "Self-organized criticality: An explanation of the 1/f noise," *Physical Review Letters*. 59, No 4 (1987): 381-384.

3 John D Sterman and Erik Mosekilde, "Business Cycles and Long Waves: A Behavioural Disequilibrium Perspective," *Massachusetts Institute of Technology*, WP No. 3528-93-MSA (January 1993).

About the Author

Dr Vishwapati Trivedi, IAS, is the former Chairman of India's National Shipping Board and has also served as a Secretary in the Ministry of Shipping. He was also the Chairman of the Inland Waterways Authority of India. Dr Trivedi is currently a member of the Governing Council of the NMF and a visiting Professor at the World Maritime University in Malmö, Sweden. He can be reached at drvtrivedi@gmail.com.