Mano River Union Economic Integration: A Mathematical Model

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Abstract

This article is an extension of Abdul Karim Bangura's 2012 E-clustering model (i.e. an innovative approach for economic policy based on the concept known as "cluster-building") for an effective regional integration of the Mano River Union (MRU). Here, I propose a mathematical economic integration model to augment Bangura's model. The objective of my model is to sum up infinitely small parts of the organization's members' economies to find a total accumulation. The model also serves as the inverse of differentiation, thereby allowing a researcher to find an original function from its derivative. This is possible because, in practice, mathematical integration models are used to solve problems in academic fields such as Physics, Engineering, and Economics, with examples including calculating distance traveled, cumulative force, or total output over time.

Keywords: Mano River Union, Economic Integration, Regional Integration, E-clustering, Mathematical Integration Model

Introduction

It makes sense to begin this section with a brief description of the Mano River Union (MRU). Thus, drawing from Abdul Karim Bangura (2012), the MRU is a regional organization of Côte d'Ivoire, Guinea, Liberia, and Sierra Leone that promotes economic integration, peace, security, and development. Established in 1973, the Union works on initiatives like border security, trade, transport, and natural resource management to foster a more stable and prosperous future for the region.

Next, Bangura denotes the concept of *E-clustering* as involving the use of modern information and telecommunication technologies (ICTs) to generate virtual clusters of interconnected businesses, academic institutions, and governments across different regions to foster economic cooperation and development (see Bangura 2012 & 2018). He suggests this approach as a way to reinvigorate the MRU by overcoming the geographical and political challenges that have historically hindered its physical integration efforts (Bangura, 2012).

Thereafter, Bangura (2012 & 2018) discusses five characteristics of the E-Clustering concept based on the fact that, as mentioned earlier, E-clustering adapts the traditional economic "cluster-building" strategy (whereby related industries geographically concentrate) to the digital age. The first characteristic is “leveraging Internet technologies”: i.e. utilizing telecommunication, information technology, multimedia, entertainment, and security technologies to support networking among participants. The second characteristic is “networking participants in a value chain”: i.e. connecting all relevant stakeholders (companies, academic institutions, research institutes, and governments) in a value-added chain to bundle their potential and competences. The third characteristic is “enhancing innovation and competitiveness”: i.e. the primary objective is to increase the innovation power and competitiveness of the partners within the cluster. The fourth characteristic is “standardized online processes”: i.e. business and government processes among partner countries can be networked and standardized using online applications. ASnd the fifth characteristic is “shared infrastructure and services”: i.e. the e-cluster would require a central infrastructure and services, including knowledge management, E-learning, E-marketplaces, and E-government platforms.

To boot, in applying E-clustering to the MRU, Bangura (2012) proffers a five-part strategy. The first part is “overcoming physical infrastructure deficiencies”: i.e. the focus on digital connectivity can bypass the immediate need for extensive and expensive physical infrastructure (e.g., roads, which are a long-term goal) in the short term, albeit some physical infrastructures such as broadband are still needed. The second part is “facilitating knowledge sharing”: i.e. generating platforms for E-learning and knowledge management can help build a skilled workforce and foster innovation across member states, thereby addressing the “human capital” challenge. The third part is “promoting E-government and E-business”: i.e. standardized online systems for business and administration can improve efficiency, reduce corruption, and attract investment. The fourth part is “enhancing regional trade and integration”: i.e. E-marketplaces and improved digital communication can facilitate cross-border trade and the free movement of goods and services among member states. And the fifth part is “building a foundation for stability”: i.e. by fostering economic interdependence and shared growth, E-clustering can contribute to long-term peace and stability in a region historically prone to conflict.

Bangura (2012) concludes by asserting that E-clustering essentially provides a flexible, modern, and potentially faster path to regional integration for the MRU by harnessing technology to build “networks of brains” and ideas. These resources are indeed the ultimate necessities for development.

A profitable question that emerges at this juncture is this: What is all this talk about mathematical integration? I broach this question in the section that immediately follows.

Mathematical Integration

There are so many works on mathematical integration that it is impossible to cite all of them in a section of an essay. I draw upon three works for the discussion here because of the ease and clarity with which they broach the subject, although without sacrificing its essentiality. These works were written by Nicolas Bourbaki (2004), Satish Shirali and Harkrishan Lal Vasudeva (2019), and testbook (2025).

For starters, according to the aforementioned authors, mathematical integration can be said to be one of the two fundamental operations of Calculus (the other being differentiation). The model can be conceptualized in the following two main ways: (1) as a method for adding up infinitesimal parts to find the whole (such as calculating area or volume); and (2) as the inverse process of differentiation (i.e. finding the antiderivative of a function) (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

Mathematical integration is noted to entail two major concepts. One concept is "antiderivative" or "indefinite integral": i.e. the indefinite integral of a function *f*(x)) is a new function *F*(x)\) whose derivative is the original function *f*(x)\) (i.e. $F^1(x) = f(x)$). The result always includes an arbitrary constant, *C,* because the derivative of any constant is zero. This is represented as follows (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025):

$$\int f(x)\ dx = F(x) + C$$

The other concept is "area under a curve" or "definite integral" which computes the exact signed area of the region bounded by the graph of a function, the x-axis, and two specific vertical lines (limits of integration), $x = a$ and $x = b$. This is represented as follows (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025):

$$\int_a^b f(x)\ dx$$

The essence of the preceding concepts hinges on the fact that the basic theorem of Calculus links the two concepts by stating that if *F*(x) is an antiderivative of *f*(x), then the definite integral can be calculated as *F*(b) – *F*(a) (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

Four methods of mathematical integration have been identified as having been utilized to find integrals, depending on the form of the function. The first method is the "basic integration formulas" or "applying standard rules directly": e.g., the power rule depicted aa follows (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

$$\int xn\, dx = \frac{xn + 1}{n + 1} + C\ for +\ -1$$

Note: in the formula, xn is x^n and xn+1 is x^{n-1}.

The second method is the "substitution method" or "U-substitution: This method is the reverse of the chain rule and helps simplify integrals by changing the variable of integration (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

The third method is the "integration by parts" technique. This method is derived from the product rule of differentiation. It is employed to integrate a product of two functions by using the following formula (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025):

$$\int u\, dv = uv\ - \int vdu$$

The fourth method is the "integration by partial fractions." This technique is utilized for integrating rational functions by breaking them down into simpler fractions (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

As hinted earlier, mathematical integration has been applied in a number of academic disciplines. First, in fields of Physics and Engineering, the technique is used to calculate quantities such as displacement from velocity, work done by a variable force, energy, center of mass, and fluid flow. Second, in the field of Geometry, the technique is employed to find areas of irregular shapes, volumes of solids, and the length of curves. Third, in the field of Economics, the technique is utilized to analyze economic models, such as calculating total cost or revenue over time. And fourth, in the field of Probability and Statistics, technique is used to calculate probabilities and expected values of random variables by finding the area under a probability density function curve (Bourbaki, 2004; Shirali and Vasudeva, 2019; testbook, 2025).

A Mathematical Economic Integration Model for the Mano River Union

A logical and easy way to develop an economic integration model for the MRU would be via producer and consumer surpluses. Unfortunately, there is no single, current figure for any MRU country's total producer or consumer surplus, as it is an economic concept that is not reported as a national aggregate. Nonetheless, economic data can be used to estimate it for specific sectors. For example, Sierra Leone's producer surplus is primarily generated by its mineral exports such iron ore, diamonds, and bauxite, as well as by agricultural products such as rice.

Thus, in this section, I identify those major products the MRU member states export from which to generate an economic mathematical integration model for the union. Hence, the model is the "integration by partial fraction" variety.. The member states' major export products are presented in Table 1.

Table 1: Common Major Exports by MRU Countries

Product	**Côte d'Ivoire**	**Guinea**	**Liberia**	**Sierra Leone**
Minerals	Gold	Gold, Aluminum Ore, Iron Ore	Gold, Iron Ore	Diamonds, Gold, Aluminum Ore, Iron Ore, Titanium
Agricultural	Cocoa, Coffee, Cashew Nuts, Palm Oil, Cotton	Cashew Nuts, Cocoa, Brazil Nuts, Coconuts	Palm Oil	Cocoa
Forestry			Rubber, Timber	Woods, Articles of Wood
Seafood				Fiish
Oil ans Gas	Crude Petroleum, Refined Petroleum	Crude Petroleum		

Source: Self-generated by the Author Using Data from the United States Central Intelligence Agency—CIA *The World Factbook* (2025)

It can be seen in Table 1 that while there are two or three member states whose major exports are the same, but only gold is the one product that constitutes the major export product of all four countries. Thus, the following integration by partial fraction formula is tenable for the MRU member states:

$$\int \frac{P(x)}{Q(x)}\, dx$$

The formula is employed as a way to decompose the integrand (economic integration, *Q*) into a sum of simpler rational expressions (in this case, gold for each of the four MRU member states (*P*). Mathematically, for a proper rational function degree of *P*(x) is less than the degree of *Q*(x).

Had a fraction for each of the four product categories displayed in Table 1 existed, the solution for the economic integration by partial fractions would have proceeded in five steps. The first step would have been "factoring the denominator. " This would involve finding the factors of the denominator of the rational fraction.

The second step would be "decomposing into partial into partial fractions" by rewriting the original fraction as a sum of fractions. The sum of these new fractions depends on the factors of the original denominator. Accordingly, for a linear factor such as $(ax + b)$, the partial fraction is $A/(ax + b)$; for a repeated linear factor such as $(ax + b\}^2$, the partial fractions are $A/(ax + b)$ +m $B/(ax + b)^2$; and for irreducible quadratic factor such as $(ax^2 + bx + c)$, the partial fraction is $(Ax + B)/(ax^2 + bx + c)$.

The third step would be "solving for thr numerators." This calls for setting the decomposed partial fraction sum equal to the original function and solving for the unknown constants (A, B, C, etc.). A common method is to multiply both sides by the original denominator to eliminate fractions and then substitute convenient values for the variable or equate coefficients of like powers of the variable.

The fourth step would be "integrate the partial fractions." This involves integrating each of the simpler fractions obtained in the decomposition. It requires using the natural logarithm rule represented as follows:

$$\int \frac{1}{x}\, dx = \ln|x| + C$$

The fifth and final step would be "combining the results." This involves summing the integrals of all of the partial fractions and adding the constant of integration, *C*.

Conclusion

The substantive finding in this article is that the integration by partial fraction formula is the only tenable economic mathematical integration model for the MRU member states. So the ultimate question that arises here is the following: Why are these finding and model essential?

The answer to the preceding question is twofold. First, the partial fraction method is essential because it allowed me to simplify complex rational expressions into a sum of simpler fractions, making them easier to integrate, solve, and analyze. Second, the economic mathematical integration model allowed me to provide a rigorous framework to analyze, predict, and understand the complex economic systems of the MRU member states. This will facilitate informed decision-making, policy formulation, and a deeper understanding of how different variables interact, ultimately helping to improve economic efficiency and forecast outcomes.

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