

Competitiveness of European Nations I

By Hemmat Safwat*

This paper applies the Knowledge-Energy Index (KEI), defined as the ratio of a nation's average hourly wage (AWH, EUR/h) to its average household electricity price (AEP, EUR/kWh). Using Eurostat data for 2021–2024, the analysis estimates KEI values for 29 European countries and groups them by relative performance. Higher wages and lower electricity prices both increase KEI, while movements in electricity prices can materially change national positions. An exploratory comparison of exports and imports for selected countries provides an additional check on the relationship between KEI groups and external competitiveness. The paper also compares KEI with the Global Knowledge Index, the European Innovation Scoreboard, and the IMD World Competitiveness Ranking. KEI is presented as a compact supplementary indicator that connects workforce productivity and knowledge with energy affordability. The findings highlight the importance of human capital, intellectual capital, and secure, competitively priced electricity in national competitiveness.

Keywords: Human capital, intellectual capital, knowledge, energy, electricity, knowledge-energy index, competitiveness

Impetus and Background of the KEI

The author started his journey in economics together with Professor Ibrahim Oweiss (Safwat and Oweiss 2002), and followed by his book (Safwat 2022). Safwat (2025) introduced the Knowledge-Energy Index (KEI), defined as the ratio of the average hourly wage (AWH, EUR/h) to the average household electricity price (AEP, EUR/kWh). A higher ratio means that one hour of labor can buy more electricity, making it a stronger signal of competitiveness. Although a national economy is far more complex than a single ratio, KEI offers a transparent link between knowledge-intensive productivity and the cost of a fundamental input: energy.

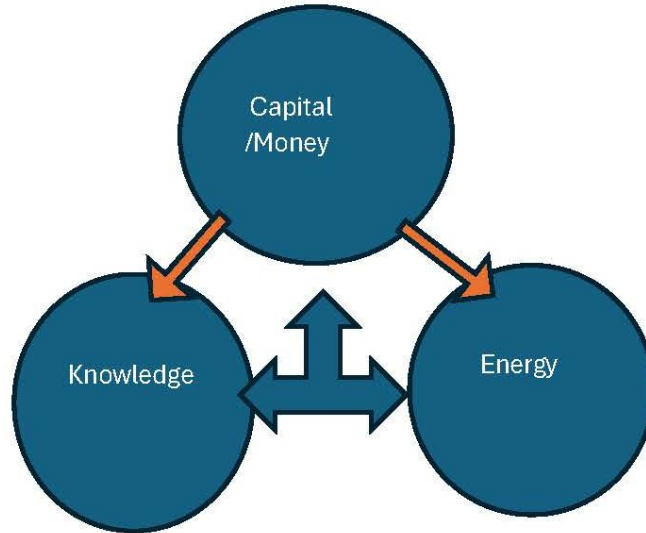
The first KEI study relied extensively on data from the U.S. Bureau of Labor Statistics (n.d.). It also included examples from several countries, but those values came from different sources and could not be compared with the same confidence as the U.S. results. Safwat (2026a) subsequently revisited KEI as a measure of competitiveness, including applications to U.S. states. Safwat (2026b) also considered the implications of KEI for artificial intelligence: in a high-wage economy, electricity-powered computation may complement or replace some labor hours when it can deliver the required output productively and reliably.

The availability of wage and household electricity-price data compiled using relatively uniform Eurostat methodologies made a broader European study possible. The coverage spans countries of different sizes and economic structures and enables

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a more consistent assessment of KEI across countries as a supplementary competitiveness indicator. Section 2 explains how the term competitiveness is used in this paper.

Figure 1. *Three Enabling Resources Underlying the Activities of an Enterprise or Nation*



Source: Author's conceptual representation.

Safwat (2025) estimated the United States KEI at approximately 200 in 2023, based on an AWH of \$33.72/h and an AEP of \$0.168/kWh. The present paper extends that approach to European countries, using euro-denominated wage and electricity-price data. KEI is interpreted as an indicator of the combined effects of human and intellectual capital on productivity and energy affordability.

Organization of the Paper

Section 2 reviews the relationship among human capital, intellectual capital, and competitiveness. Section 3 presents KEI estimates for European countries. Section 4 discusses challenges and policy opportunities. Section 5 compares KEI rankings with established measures of knowledge, innovation, and competitiveness, and Section 6 presents the conclusions.

A companion paper, *Competitiveness of European Nations II: Influence of National Economic Structure and Profile*, examines conventional economic indicators for representative countries across the KEI groups. The two papers provide complementary perspectives: Paper I develops the KEI comparison, while Paper II examines the economic structures underlying selected results.

Human Capital, Intellectual Capital, and Competitiveness

Economic growth theory established the importance of human capital and the closely related concept of intellectual capital. Key contributions include Schultz (1961), Becker (1964), Arrow (1962), Solow (1956), Romer (1986), and Lucas (1988). Subsequent work expanded the analysis to organizational knowledge, innovation, capabilities, and the practical deployment of expertise (Davenport and Prusak 1998, Kessler and Lulfesmann 2006, Spender 2011, Leoni 2023).

Trade theory provides a foundational basis. Smith (1776) and Ricardo (1817) examined specialization and comparative advantage. Heckscher and Ohlin (1933) emphasized factor endowments, while Samuelson (1948), Krugman (1979, 1980), and Melitz (2003) further developed the relationships among factor prices, scale, firm heterogeneity, and international trade.

The paper does not repeat the detailed theoretical discussion in Safwat (2025). Its purpose is to apply that foundation. Governments, enterprises, and individuals invest in human capital, while research and development build intellectual capital and support innovation. A more capable workforce can produce goods and services that other countries seek, strengthening exports and productivity. When these gains are sustained, workers can command higher compensation. This relationship among productive capability, wages, and international performance explains the paper's use of competitiveness in its title.

KEI is deliberately simple. It does not capture a nation's entire economy; instead, it offers a concise view of how the economic value of an hour of labor compares with the cost of household electricity. Paper II complements this measure with conventional economic comparisons.

KEI Estimates for European Nations

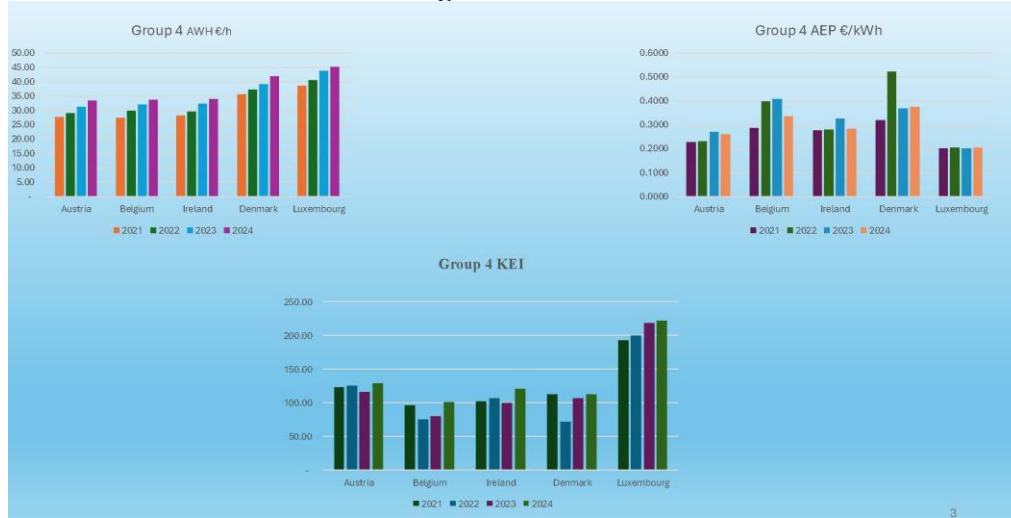
For a given year, a nation's KEI is calculated as follows: $KEI = AWH \div AEP$, where AWH is the average hourly wage in EUR/h and AEP is the average household electricity price in EUR/kWh. Comparability is strongest when both variables use consistent definitions, sources, and reference periods.

Data availability and consistency led to the selection of 2021–2024. We chose these series because their definitions and Eurostat methodology appeared consistent across the study period and participating countries. AWH was derived from annual compensation per employee and annual hours worked, with monetary values reported in euros. Because Eurostat publishes household electricity prices for two semesters each year, the arithmetic mean of the first- and second-semester prices was used to estimate annual AEP. The selected household band covers annual consumption between 1,000 and 2,499 kWh, and the prices include taxes, levies, and VAT. Automated links between the working Excel files and Eurostat could not be reliably maintained; therefore, future calculation files should record the dataset code, source release, and retrieval date for each imported series.

The initial analysis covered 26 countries, grouped into four performance groups, with higher-numbered groups indicating higher KEI values. The Netherlands,

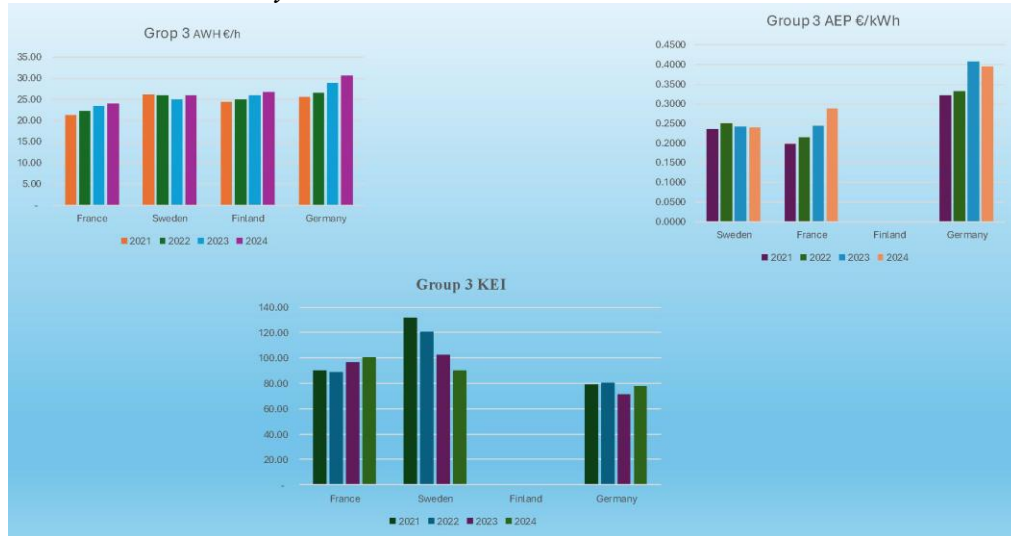
Switzerland, and Norway were added once consistent data became available, expanding the comparison to 29 countries and creating Group 5.

Figure 2. *AWH, AEP, and KEI Values for Group 4, 2021–2024: Austria, Belgium, Ireland, Denmark, and Luxembourg*



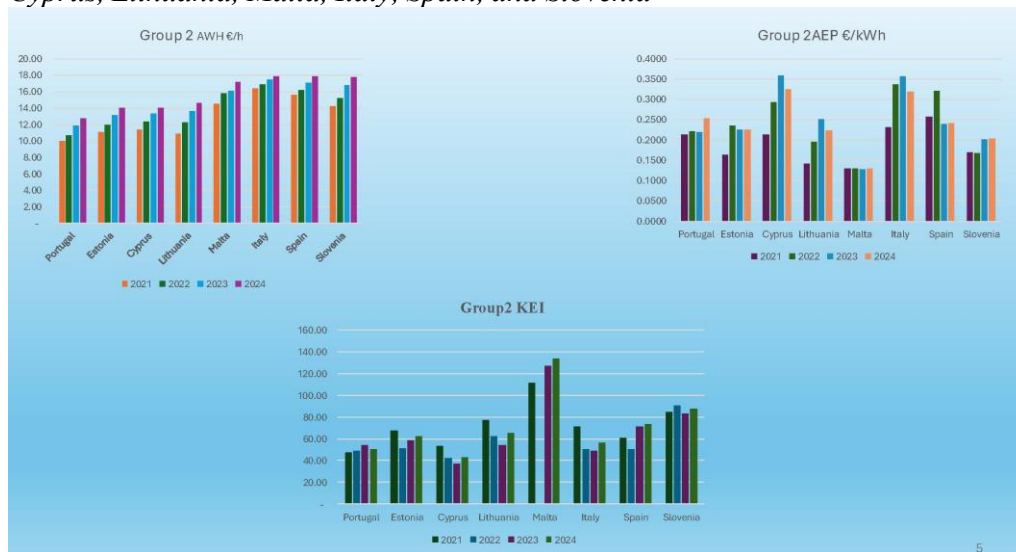
Source: Author's calculations using Eurostat data.

Figure 3. *AWH, AEP, and KEI Values for Group 3, 2021–2024: Sweden, France, Finland, and Germany*



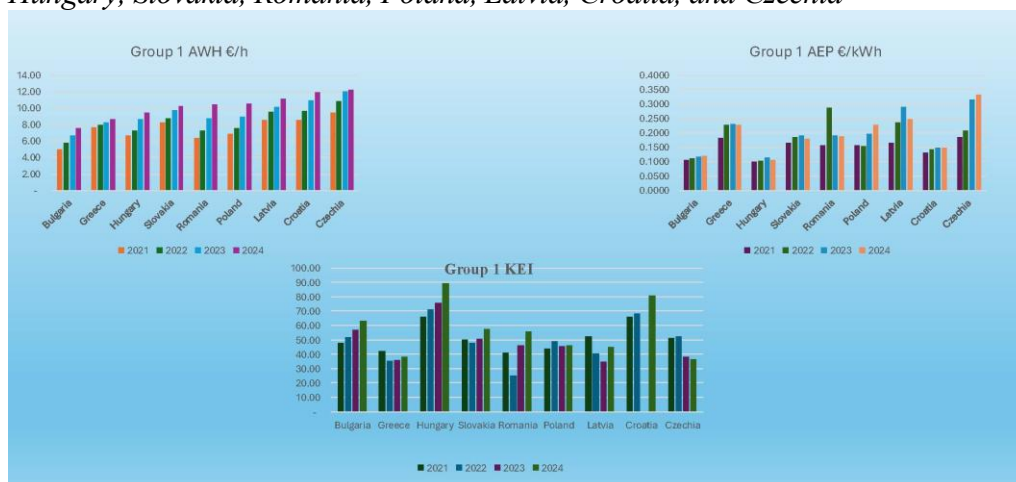
Source: Author's calculations using Eurostat data.

Figure 4. *AWH, AEP, and KEI Values for Group 2, 2021–2024: Portugal, Estonia, Cyprus, Lithuania, Malta, Italy, Spain, and Slovenia*



Source: Author's calculations using Eurostat data.

Figure 5. *AWH, AEP, and KEI Values for Group 1, 2021–2024: Bulgaria, Greece, Hungary, Slovakia, Romania, Poland, Latvia, Croatia, and Czechia*



Source: Author's calculations using Eurostat data.

Across Figures 2–5, AWH generally increases over the study period, whereas AEP is more volatile. The figures also show how comparatively low electricity prices can affect KEI. Table 1 summarizes the KEI estimates covered in the four groups of Figures 2–5 plus a fifth group; The Netherlands, Switzerland and Norway.

Table 1. *Illustrative KEI Calculations for 11 European Countries, 2024*

Country	Annual compensation/employee €	Annual hours worked	Derived €/h	Elec. S1 €/kWh	Elec. S2 €/kWh	Annual avg €/kWh	KEI	Group
Norway	80,000	1,420	56.30	0.200	0.180	0.190	296.32	5
Switzerland	102,000	1,550	65.80	0.300	0.300	0.300	219.33	5
The Netherlands	60,000	1,430	42.00	0.260	0.250	0.255	164.71	5
Denmark	67,000	1,450	46.20	0.380	0.370	0.375	123.20	4
Finland	55,000	1,550	35.5	0.222	0.218	0.22	161.36	3
Germany	57,000	1,350	42.20	0.400	0.390	0.395	106.84	3
Malta	33,000	1,850	17.80	0.130	0.130	0.130	136.92	2
Spain	34,500	1,600	21.60	0.250	0.240	0.245	88.16	2
Croatia	21,500	1,800	11.90	0.160	0.159	0.160	74.38	1
Greece	25,500	1,830	13.90	0.235	0.225	0.230	60.43	1
Poland	20,600	1,790	11.50	0.226	0.230	0.228	50.44	1

Source: Author's calculations using Eurostat wage, hours-worked, and household electricity-price data.

Norway, Switzerland, and the Netherlands form Group 5 and are highlighted in magenta. Finland, Malta, and Croatia are also highlighted because we obtained their data in a later Eurostat search. Eurostat values for Norway, Switzerland, the Netherlands, and Finland were initially marked as provisional and later revised. This experience shows why calculation files should retain the precise source release and retrieval dates used for each estimate.

In this paper, competitiveness means a country's relative ability to produce goods and services valued by domestic and foreign buyers. Strong export performance is a practical sign of this advantage. The five KEI groups provide a concise comparison of one aspect of this broader concept, rather than a complete ranking of national economic performance.

Table 2 presents an exploratory trade comparison of selected countries from KEI Groups 1–5. It reports GDP, exports, and imports of goods and services as percentages of GDP for 2024. The comparison is intended as a cross-check on the KEI grouping; it does not establish that KEI alone determines trade performance.

Table 2. *GDP, Exports, and Imports of Selected Countries by KEI Group, 2024*

KEI Group	Country	GDP Current USD USD Billion	Exports Percent of GDP	Imports Percent of GDP
Group 1	Greece	256	42.0%	47.3%
	Romania	383	35.6%	41.7%
	Poland	918	52.3%	48.3%
Group 2	Malta	25	118.5%	99.3%
	Spain	1,726	37.3%	33.0%
Group 3	Finland	299	41.9%	41.5%
	Germany	4,686	41.8%	37.9%
Group 4	Denmark	425	71.0%	60.8%

KEI Group	Country	GDP Current USD USD Billion	Exports Percent of GDP	Imports Percent of GDP
Group 5	The Netherlands	1,214	82.4%	71.4%
	Switzerland	970	72.2%	61.9%
	Norway	501	47.5%	33.9%

Source: Author's compilation based on World Bank WDI and United Nations National Accounts AMA data.

Among the selected Group 1 countries, imports exceed exports in Greece and Romania, whereas Poland shows the reverse. In the selected countries in Groups 2–5, exports are generally at or above imports, with Finland close to balance. These findings align with the proposed competitiveness interpretation, but the sample is small, and trade ratios are also shaped by country size, economic structure, multinational activity, and participation in regional value chains. Malta's ratios, which exceed 100% of GDP, highlight the importance of these structural effects. The trade comparison should therefore be viewed as supporting evidence for further testing, not as proof of causality.

Challenges and Opportunities

Countries seeking to improve KEI and national competitiveness should consider both near-term measures and medium-term structural planning. Historical KEI values provide a baseline, and future improvement depends on sustained productivity growth, higher real wages, and access to secure, competitively priced electricity.

Investing in human and intellectual capital can boost productivity and support higher wages. At the same time, power-system planning must ensure that adequate generation, networks, storage, fuel diversity, and efficient demand management support additional economic activity. KEI therefore highlights the interaction between workforce capability and energy-system performance. The transition toward lower-carbon electricity creates opportunities but can also increase system costs: adding variable wind and solar generation requires complementary networks, storage, flexible generation, and operating reserves to maintain reliability and affordable electricity prices.

Comparison with Other Competitiveness Rankings

Safwat (2025) compared the 2023 Global Knowledge Index (GKI) rankings with the KEI rankings for the same year. A broader comparison is useful because several organizations publish national rankings on knowledge, innovation, or competitiveness. These measures differ in scope, data requirements, and methodology and should therefore be treated as complementary perspectives rather than as equivalent indicators.

Table 3. Comparison of KEI, GKI, EIS, and IMD Rankings, 2024

Pertinent to KEI Ranking			2024		
KEI Groups	Nation	KEI Ranking	GKI Ranking	EIS Ranking	IMD Ranking
Group 5	Norway	1	7	N/A	10
	Switzerland	2	3	N/A	2
	The Netherlands	3	5	4	
Group 4	Luxembourg	4	6	8	23
	Denmark	5	4	1	3
	Ireland	6	14	7	4
	Belgium	7	9	5	18
	Austria	8	8	6	26
Group 3	Germany	9	11	9	24
	France	10	15	12	
	Finland	11	2	3	15
	Sweden	12	1	2	
Group 2	Slovenia	13	13	13	
	Spain	14	18	14	
	Italy	15	21	16	
	Malta	16	12	17	
	Lithuania	17	22	18	30
	Cyprus	18	19	10	
	Estonia	19	10	11	
	Portugal	20	16	19	
Group 1	Czechia	21	17	15	29
	Croatia	22	23	22	
	Latvia	23	20	25	
	Poland	24	24	23	
	Romania	25	28	27	
	Slovakia	26	25	24	
	Hungary	27	26	21	
	Greece	28		20	
	Bulgaria	29	27	26	
			Missing Greece	Missing Switzerland & Norway	Only 13 European countries appeared on the Top 30 Countries

Global Knowledge Index 2024

The Global Knowledge Index was developed by the United Nations Development Program Regional Bureau for Arab States and the Mohammed bin Rashid Al Maktoum Knowledge Foundation. Introduced in 2017, it assesses pre-university education; technical and vocational education and training; higher education; research, development, and innovation; information and communications technology; the economy; and the enabling environment. Together, these areas reflect the breadth and depth of a country's knowledge system.

European Innovation Scoreboard 2024

The European Innovation Scoreboard evaluates national innovation-system performance using indicators drawn mainly from European sources. It covers human resources, research systems, digitalization, finance and support, firm investment, collaboration, intellectual assets, employment effects, and environmental sustainability.

IMD World Competitiveness Ranking 2024

The International Institute for Management Development publishes detailed country competitiveness profiles and rankings. It bases its overall score on numerous indicators grouped into economic performance, government efficiency, business efficiency, and infrastructure. Comparing KEI, GKI, EIS, and IMD can reveal broad agreement and important divergence, provided you keep their different scopes in view¹.

Table 3 compares country positions across KEI, GKI, EIS, and IMD. The KEI, GKI, and EIS columns approximate rankings among the European countries considered, whereas IMD positions are drawn from a broader international ranking. Lower ranking numbers indicate stronger performance. Greece is absent from the GKI comparison; Switzerland and Norway are absent from EIS; and only 13 of the European countries shown appear among the top 30 countries in the IMD table. These coverage differences must be considered when interpreting the comparison.

GKI, EIS, and IMD are produced by organizations with extensive data infrastructures. By contrast, KEI—introduced by the author in 2025—is intentionally compact and is developed in this paper and its companion study.

Conclusions

Over the long term, a higher average wage can indicate productivity growth and stronger human-capital performance. Lower electricity prices directly raise KEI and may improve competitiveness by reducing energy costs. By combining AWH and AEP, KEI connects two basic economic inputs: the value of knowledge-based labor and the cost of energy. The data used in this paper are consistent enough for an exploratory comparison, subject to the provisional values, revisions, and source-traceability limitations identified above.

AWH is a useful indicator of a nation's workforce contribution to the economy, since sustained compensation depends partly on productivity and the value of the goods and services produced. These capabilities can also support exports. However, wages are also shaped by institutions, labor market conditions, taxes, and sector composition, so KEI should be interpreted alongside broader economic evidence.

Countries in KEI Groups 1 and 2 may improve their positions by strengthening human capital, expanding training, moving toward higher-value-added activities, and ensuring reliable electricity at competitive prices. The appropriate policy mix

¹Author's compilation using KEI calculations, GKI (2024), EIS (2024), and IMD (2024).

will vary by country and should be evaluated using broader economic and sectoral evidence.

Eurostat provides the primary wage and electricity-price data needed to estimate KEI for European countries. Continued publication of consistent annual data should make future updates feasible and enable KEI to be monitored over time. Eurostat's integrated structure supports comparisons across multiple parameters, although extracting fully traceable series requires familiarity with its datasets and codes. For the United States, BLS data distributed directly and through FRED offer a relatively straightforward route to wage series. Future KEI files should retain dataset identifiers, retrieval dates, and revision status for every imported value.

The comparison with GKI, EIS, and IMD confirms that no single ranking captures every dimension of competitiveness. KEI's value lies in its simplicity and in the direct economic interpretation of its two components. Further research should test its stability over time, assess its sensitivity to alternative definitions of wages and electricity prices, and examine its relationship with productivity, innovation, investment, exports, and economic growth. Paper II extends this work by comparing conventional economic parameters, although the results remain limited by the available tabular data.

KEI is a new concept, and its simplicity may invite skepticism. That simplicity is deliberate: the index combines a production-side signal, the economic value of an hour of labor, with a consumption-side energy-price signal. The concept's positive initial reception supports continued investigation, but acceptance should depend on transparent data, reproducible calculations, sensitivity testing, and evidence that KEI provides information beyond established competitiveness measures.

Acknowledgments

The author dedicates this work to the late Professor Ibrahim Oweiss of Georgetown University, who died in November 2023. Professor Oweiss collaborated with the author beginning in 1988 and made significant contributions to the author's earlier work on knowledge and energy.

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