ECONOMIC COMPLEXITY THEORY AND ITS APPLICATIONS: A CASE STUDY OF ARMENIA

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Key words: complexity economics, economic complexity, economic complexity index, fragile states index, product space, frontier technology, export, economic development

Introduction

Over the past three decades, there has been growing academic interest in complexity theory and, in this context, complexity economics, driven by the desire to better understand how economic systems function, adapt and evolve. Complexity economics sees the economy as a system that is part of a larger system and consists of smaller parts that can be treated like subsystems. It tries to study these subsystems, how they change, why they change, and what the results of these changes are. Complexity economics uses models from complexity theory to view and model the economy as a complex adaptive system [Arthur, 2013]. All post-Soviet countries, like most Latin American countries, on the recommendations of international institutions, intensively implemented the policies (trade and financial liberalization, privatization, macroeconomic stability) of the so-called Washington Consensus, which did not meet the expectations of many countries: for more than three decades, most countries with transition economies have failed to implement high-quality structural changes that would contribute to a significant increase in productivity and human well-being. Economic liberalization and, through it, involvement in economic globalization processes, was supposed to enable transition countries, including the Republic of Armenia, to undertake important structural reforms to transition to the market system. Why? The answer is: because the economic reforms were based on considerations of standard economic theory.

Taking into account the prospects of the paradigm of economic complexity and with the aim of laying the principles of the economy of complexity at the basis of the country's economic policy, the Government of the Republic of Armenia has set medium-term and long-term goals for increasing the level of complexity of the country's economy in its program, which makes the study of science and practice in this area relevant.

Methodology

In this article, data is used from the Harvard Growth Lab Atlas of Economic Complexity, Fragile States Index and World Bank. Also, in this context, macroeconomic data from countries with transition economies is analyzed. A review of the literature related to economic complexity and complexity economics was conducted. The relationship between GDP per capita and the economic complexity index is examined using data from 134 countries.

Literature review: *Understanding Complexity Economics*

Since the 1990s, economists have begun exploring the economy as an evolving complex system, and out of this exploration has come a different approach — complexity economics. Complexity economics sees the economy — or the parts of it that interest us — as not necessarily in equilibrium, its decision makers (or agents) as not superrational, the problems they face as not necessarily well-defined, and the economy not as a perfectly humming machine but as an ever-changing ecology of beliefs, organizing principles and behaviors [Arthur, 2021, 136].

Table 1. Differences between neoclassical, complexity economics [Arthur, 2021, 143]

Feature*	Neoclassical economics	Complexity economics
Agents	Representative, with 1, 2, *N* or a distribution of types	Diverse
Organizing principle	Equilibrium. Agent behavior consistent with aggregate outcome.	Nonequilibrium. Agent behavior reacts to aggregate outcome.
Metaphor	Well- functioning machine	Ecology: of forecasts, actions, strategies
What is faced by agents	Well- defined problem	Ill- defined situation
Behavior	Agents optimize	Agents face fundamental uncertainty, they try to make sense, explore
Structural change	The equilibrium shifts	Novelty causes endogenous restructuring
Rationality	Perfect and boundless	Rationality is usually not defined
Feedbacks	Diminishing returns	Increasing, diminishing, returns
Time	Equilibrium is timeless	History and path taken matter
Dominant theme	Allocation of resources	Formation of structures
System	Closed to new behavior	Open. System can be exploited
Methods used	Mathematics (quantities, incentives in balance)	Mathematics and computation (algorithmic and event-driven)
Temporary phenomena	Excluded by equilibrium	Possibly emerge
Interaction	Homogeneous	Channeled by networks
Evolution of economy	Outcomes usually seen as in stasis. Not evolving	Economy self-creating, in perpetual novelty
*) Entries are general; there may be exceptions to them in particular studies.		

Traditional economic theory could not explain, much less predict, the near collapse of the financial system and its long-lasting effects on the global economy. Since the 2008 crisis, there has been increasing interest in using ideas from complexity theory [Battiston et al, 2016]. As Brian Arthur[1] explains the standard neoclassical theory of financial markets cannot account for actual market phenomena such as the emergence of a market psycho-

[1] Arthur is one of the early economic researchers in the emerging complexity field. Specifically, his complexity studies focused on the "economics of high technology; how business evolves in an era of high technology; cognition in the economy; and financial markets".//"Short Background: Brian Arthur". Santa Fe Institute. Retrieved on 27 October 2007.

logy, price bubbles and crashes, and random periods of high and low volatility [Arthur, 2021, 139]. Much, in this regard, is due to the significant differences between neoclassic and complexity economics, which is presented in Table 1.

Some concepts and methods used in complexity economics to understand complex systems are as follows (Figure 1) [Venter and Varma, 2023]: *Value; Interactions; Feedback loops; Networks; Open systems & Closed systems; Algorithms and equations; Emergence; Decision making and behavior; Non-equilibrium; Time dependence and dynamic vs linear change; Economic development and growth; Agent-based models and simulations; Complexity theory and Chaos theory; Borrowing from other disciplines.*

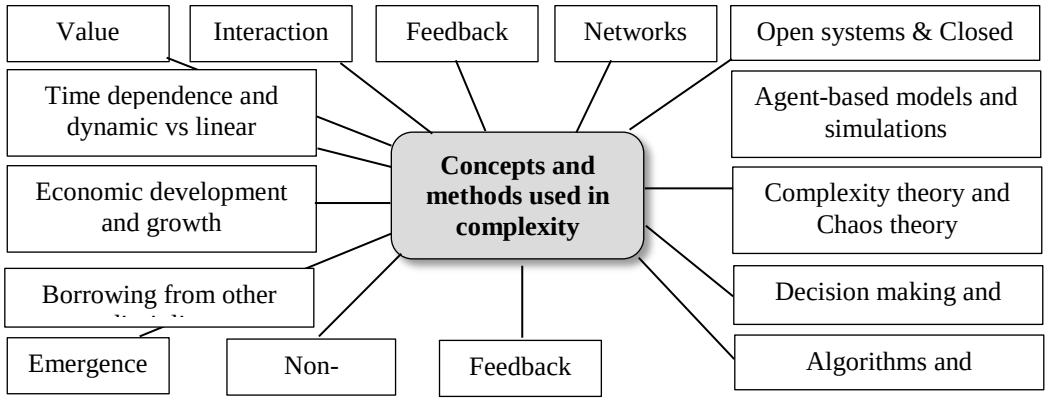

Figure 1. Concepts and methods used in complexity economics [Venter & Varma, 2023][1]

Value. In contrast to traditional economic theory, Value is defined more broadly in complexity economics. Value is found in networks: social value is found in social networks, financial value flows in financial networks, and ecological value comes from ecological networks.

Interactions. People in their pursuit of the things we value, and for organizations to create value, we interact with each other and with the environment around them. The global economy is one big network connecting not only the interactions of billions of people performing different specialized functions but also the cultural and ecological systems [Arthur, 2013]. In this context, complexity economics would be able to work with all of these interactions, not just the ones that were traditionally thought of as falling within the 'borders' of the economy [Gräbner, 2017].

Feedback loops. Cycles emerge whereby our actions create new institutions, these new institutions then facilitate interactions among economic agents, and from the new inte-

[1] Constructed by the author based on the source: Dennis Venter, D., Varma, A. Think Complexity Economics is too Complicated? Then this is for you. Exploring Economics, 2023.//https://www.exploring-economics.org/en/discover/easy-explanation-of-complexity-econ/

ractions emerge new institutions. Feedback loops is a term used by physicists and mathematicians, some of the founders of complexity economics were physicists. However, the general idea of 'feedback loops' is much older. It is known as "cumulative causation" and Thorstein Veblen was the first to talk about it as a way of thinking about economics: "The modern scientist is unwilling to depart from the rest of causal relation or quantitative sequence. When he asks the question "why", he insists on an answer in terms of cause and effect. He wants to reduce his solution of all problems to terms of the conservation of energy or the persistence of quantity. This is his last recourse and it has in our time been made available for the handling of schemes of development and theories of a comprehensive process by the notion of cumulative causation" [Veblen, 1898].

Networks Social networks permeate our social and economic lives. The countless ways in which network structures affect our well-being make it critical to understand: (i) how social network structures impact behavior, and (ii) which network structures are likely to emerge in a society [Jackson, 2010]. People and organizations are embedded in overlapping networks. These include social networks, cultural networks, technological networks, production networks, consumption networks, financial networks, and many other types of networks. Resources flow through these networks. How these resources become available to us depends on where we lie in the network as well as the structure of the network itself. The value flowing through the network may increase exponentially every time a new person or organization joins and the number of possible interactions among them, too. Value is something that emerges from the network connections. The value of the total network is higher than the value of each part on its own. Billions of actions of different firms are coordinated in the types of networks which results in complex services and products that no one person or organization can perform or create by themselves individually [Jackson, 2010].

Open systems and closed systems Complexity economics, by contrast, teaches us that the economy is permanently open to response and that every part of it is open to new behavior — to being exploited for gain, or to abrupt changes in structure [Arthur, 2013]. Open systems are so integrated with other systems that they cannot be defined by their boundaries [Bertalanffy, 1988]. Studying the economy as a complex system implies that we see it as an open system that cannot be studied as separate from other systems like the cultural or ecological system. If we see the economy as a closed system, we cannot study what happens when it takes in value from other systems such as social value from the cultural system and ecological value from nature. Neither can we study the influence that the economy has on those systems, for example, how economic systems bring out certain behaviors in people or cause environmental degradation [Arthur, 2013].

Non-equilibrium Closed systems will reach the equilibrium because there are a finite number of variables being considered and because they are shielded from the real world

[Arthur, 2013]. Open systems will not exhibit equilibrium because they are in a constant state of change, being influenced by other systems and influencing these systems in continuous cycles. In other words, inputs and outputs change as the whole system changes [Farmer & Geanakoplos 2009]. Unlike standard economics which is based on equilibrium from modeling the economy as a closed system, complexity economics sees the economy as an open system that is never in equilibrium.

Algorithms and equations Closed systems use linear equations while open/complex systems are modeled with algorithms which are then put into code and run by a computer. These simple rules or algorithms can then create complex interactions and emergence. "You can see some of these examples in the last section of this If you play the algorithm out in your mind you see something interesting. It can set in motion a sequence of events that never end, because each of the events may trigger a cascade of further events. A novel technology may cause further technologies to be added…"[Arthur, 2013].

Emergence Despite its ubiquity and importance, emergence is an enigmatic, recondite topic, more wondered at than analyzed. Emergence describes the ability of individual components of a large system to work together to give rise to dramatic and diverse behavior. Parts of a system do things together that they would not do alone. "... patterns unfold into institutions and cause shifts in our culture, and financial bubbles develop due to individual actions" [Holland, 2014]. It is almost as if the rules of the game are being invented by some unseen force or by the game itself, this is said to be an emergent phenomenon related to self-organization. "Understanding the origin of these regularities, and relating them to one another, offers our best hope of comprehending emergent phenomena in complex systems" [Holland, 2000].

Decision making and behavior How people and organizations make decisions is a central part of economics and the complexity economics. Of particular interest are individual choices in the allocation of resources and how these micro-level actions interact to give rise to macro-level patterns of organization [Goodwin et al., 2022].

Since individuals interact in a complex system, they change their actions and strategies in response to the outcome they mutually create [Arthur, 2021]. As far as people choose, complexity economics is aligned with the idea that people use mental shortcuts (heuristics) that make sense in the culture and environment that they are accustomed to, and when their choice turns out to be wrong it is due to a misinterpretation or misrepresenttation of the situation. These mental shortcuts can give more optimal results than probability theory calculations that neoclassical economics believe people implicitly use.

So, in real life, these mental shortcuts may emerge from people being able to interpret nuances in situations over time and learning from experts. Whenever we use our exper-

tise and gut feelings instead of probability equations, we are working with heuristics [Todd & Gigerenzer, 2012].

Complexity economists interpret a wrong decision as the result of a wrong fit between the heuristic used and the situation, they see it as the most rational choice given the mental toolkit of the decision maker.

Time dependence and dynamic vs linear change Models developed by neoclassical economics that describe phenomena with a few lines on a graph are geared toward hypothetical static situations. These will not produce useful results as the whole system evolves over time. Instead, complexity economics tries to understand how the complex system itself changes over time.

Economic development and growth Since the economy is seen as a complex adaptive system that evolves over time, complexity economics focuses on the non-equilibrium processes that transform the economy from within. The focus is on technological innovation and new business models that lead to a process of creative destruction in an economy that grows in a somewhat organic way. The focus is on how changes in one part led to new opportunities or problems in others as the whole thing evolves with different industries and sectors becoming interdependent[1]. Out of this process of evolution, we get what we might call economic growth, not in the traditional sense of gross output of goods and services but in terms of qualitative structural transformation in becoming more differentiated and integrated to exhibit greater levels of complexity.

Agent-based models and simulations These are the methods used by complexity economics to get from the micro level to the macro level. Instead of simply getting an aggregate of all the micro variables as if we are dealing with a closed system, it looks at how other systems influence the economy in real time and try to simulate it with computers to find the rules of these interactions.

Complexity theory and Chaos theory Complexity Theory is the overall study of complex systems. It is not just in economics that we can study such systems. How storms emerge, the way ant colonies work, human evolution, water networks, and lots of other phenomena are examples of complex systems [Kauffman, 1995]. Chaos theory states that within what might appear as random chaos in complex systems, there are actually underlying patterns, interconnection, constant feedback loops, and self-organization.

Borrowing from other discipline Complexity economics can gain a lot by borrowing from the deep perspectives found in institutional economics, behavioral economics, and ecological economics [Gräbner, 2017].

[1] Harvard Growth Labs, 2023, Atlas of Economic Complexity. Accessed 15 January 2023. https://atlas.cid.harvard.edu/

Analysis: Some applications of complexity economics
Why nations fail? *Transition Countries Fragile States Index*

Economic liberalization and, through it, involvement in economic globalization processses, was supposed to enable transition countries, including the Republic of Armenia, to undertake important structural reforms to transition to the market system.

All post-Soviet countries, like most of Latin American countries, on the recommendations of international institutions, intensively implemented the so-called Washington Consensus policy. "Washington Consensus" term later became widely used in a pejorative way to describe the increasing harmonization of the policies recommended by those institutions. It often refers to a dogmatic belief that developing countries should adopt market-led development strategies that will result in economic growth that will "trickle down" to the benefit of all[1].

Meanwhile, as became obvious later (first in the case of Latin American countries, and the 1990s in post-Soviet countries), the principles of economic policy (trade and financial liberalization, privatization, macroeconomic stability) formulated by the British economist John Williamson within the framework of the Washington Consensus did not meet the expectations of many countries: for more than three decades, most countries with transition economies have failed to undergo qualitative structural changes that would contribute to a substantial increase in productivity and the well-being of people.

In that regard, a recipient of the Nobel Prize winner in Economic Sciences Joseph Stiglitz noted: "Globalization and the introduction of a market economy has not produced the promised results in Russia and most of the other economies making the transition from communism to the market. These countries were told by the West that the new economic system would bring them unprecedented prosperity. Instead, it brought unprecedented poverty: in many respects, for most of the people, the market economy proved even worse than their Communist leaders had predicted" [Stiglitz, 2002].

One of the confirmations of the correctness of Joseph Stiglitz's reasoning can be found in the Countries Fragile States Index (FSI), according to which most of the transition economies have been in a precarious state for a long time (table 2). As shown in the table, transition economies are divided into eight groups: "Sustainable", "More Stable", "Stable", "Less Stable," "Low Warning", "Warning", "Low Warning", "High Warning", "Alert" and the post-Soviet countries (excluding the Baltic countries) into three groups: Low Warning" (Armenia, Belarus, Georgia, Kazakhstan, Moldova, Turkmenistan, Uzbekistan), "Warning" (Azerbaijan, Kyrgyz Republic, Tajikistan), "High"Warning" (Russia), "Alert" (Ukraine): On the other hand, the countries of the former socialist camp and

[1] Washington Consensus// https://www.britannica.com/money/Washington-consensus

the Baltic countries have completed the transition to a market economy with relative success, but with varying degrees of sustainability.

In transition						Transition complete		
Country	FSI score	Category	Country	FSI score	Category	Country	FSI score	Category
Albania	56.8	Less Stable	Laos	74.7	Warning	Bulgaria	51.8	Less Stable
Armenia	67.5	Low Warning	Moldova	67.4	Low Warning	Croatia	51.8	Less Stable
Azerbaijan	72.7	Warning	Montenegro	58	Less Stable	Czech Republic	40.2	Stable
Belarus	69.9	Low Warning	North Macedonia	-	-	Estonia	38.6	More Stable
Bosnia and Herzegovina	72.3	Warning	Russia	80.7	High Warning	Hungary	48.8	Stable
Botswana	55.3	Less Stable	Serbia	67.9	Low Warning	Latvia	43.3	Stable
Cambodia	80.3	High Warning	Vietnam	58.3	Less Stable	Lithuania	39.4	More Stable
China	65.1	Low Warning	Tajikistan	74.2	Warning	Poland	45.2	Stable
Georgia	71.9	Low Warning	Turkmenistan	64.5	Low Warning	Romania	53	Less Stable
Kazakhstan	60.6	Low Warning	Ukraine	95.9	Alert	Slovakia	37.8	More Stable
Kyrgyz Republic	75.6	Warning	Uzbekistan	66.8	Low Warning	Slovenia	27.3	Sustainable

Table 2. Transition Countries Fragile States Index[1]

Why do some countries become rich, while others remain impoverished? Why nations fail? These questions have long time interested the 2024 Nobel Prize winners in Economic Sciences, Daron Acemoglu, James Robinson and Simon Johnson, and the search for answers to them has led to the creation of valuable works that have become world best-sellers [Acemoglu & Robinson, 2012].

Scholars have been working to identify the framework of factors that explain differences in prosperity. Their work has taught us about the importance of institutions [Acemoglu et al., 2001; Acemoglu & Robinson, 2012; North, 1990], technology [Romer, 1990; Romer, 1994], human capital, cultural values [Harrison, 1992], cultural capital [Bourdieu, 1986], and social capital [Coleman, 1988; Fukuyama, 1995; Knack & Does, 1997; Knack, 2002]. It has long been clear that economic prosperity cannot be narrowly tied to indivi-

[1] Compiled by the author based on the source Failed States 2024// https://worldpopulationreview.com/country-rankings/failed-states

dual factors, because in fact, the differences between rich and poor countries are manifold and include many very specific factors, whose interactions can be understood using complexity theory. Therefore, the above questions seem to need to be answered through the prism of complexity economics and the country's economic complexity. Complexity Economics can help us understand the development characteristics of national economies using indicators that focus on a broader range of factors. Economic complexity offers a potentially powerful paradigm to understand key societal issues and challenges of our time. The underlying idea is that growth, development, technological change, income inequality, spatial disparities, and resilience are the visible outcomes of hidden systemic interactions [Balland et al. 2022].

For a transition economy as Armenia, technological advancement and innovation are critical to improve an economic structure for rising productivity and lifting the long-term growth potential, the role of which, as a fundamental predictor of future growth, namely through economic complexity, is examined in the study by Ricardo Hausmann et al [Hausmann et al. 2013].

Evolution of Armenia's Economic Complexity

The RA Government's 2021-2026 Program (Program) states: "Taking into consideration the fact that the potential for long-term economic growth is significantly conditioned by the level of economic complexity, the Government continues to consider essential increase of economic complexity of Armenia as a priority. For the purpose of increasing the economic complexity of Armenia, it is envisaged to implement complex measures targeted at technological rearmament of enterprises, as well as penetration into new international markets and strengthening of the existing positions"[1]. In this regard, the target has been established "to make the economic complexity index from -0.39 to 0.1 over the medium term and create grounds for being classified among the countries with high economic complexity in the course of 10 years"[2].

Armenia ranks as the 92st (2021) in the Economic Complexity Index (ECI) ranking (ECI -0.51). It is not advisable to consider ECI-2022 due to the fact that the jump in ECI from -0.52 to 0.18 (rank 54) in 2022 is due to a sharp increase in the re-export of complex products and, therefore, does not reflect the real state of complexity of the country's economy. The significant growth in the export of complex products to Russia is due to the introduction of economic sanctions against this country, which cannot serve as an indicator of a qualitative change in exports, which is not a reflection of structural changes in the Armenian economy in the context of economic complexity. Therefore, in the methodology for calculating the index of economic complexity developed by the Harvard

[1] Programme of the Government of the Republic of Armenia 2021-2026. August 2021, p.34.
[2] Programme of the Government of the Republic of Armenia 2021-2026. August 2021, p.35.

University Growth Laboratory, it is advisable to introduce a correction coefficient to avoid distortion of the real state and ensure correctness in cross-country comparisons. With regard to the phenomena that have taken place in Armenia (since 2022), it seems appropriate to introduce the term "pseudo-economic complexity". Compared to 2000, Armenia's economy has become less complex, worsening 56 positions in the ECI ranking (Figure 1). The deterioration of the situation in Armenia is due to the lack of export diversification. In the future, it seems that Armenia will be able to take advantage of the few opportunities to diversify its production using its existing know-how.

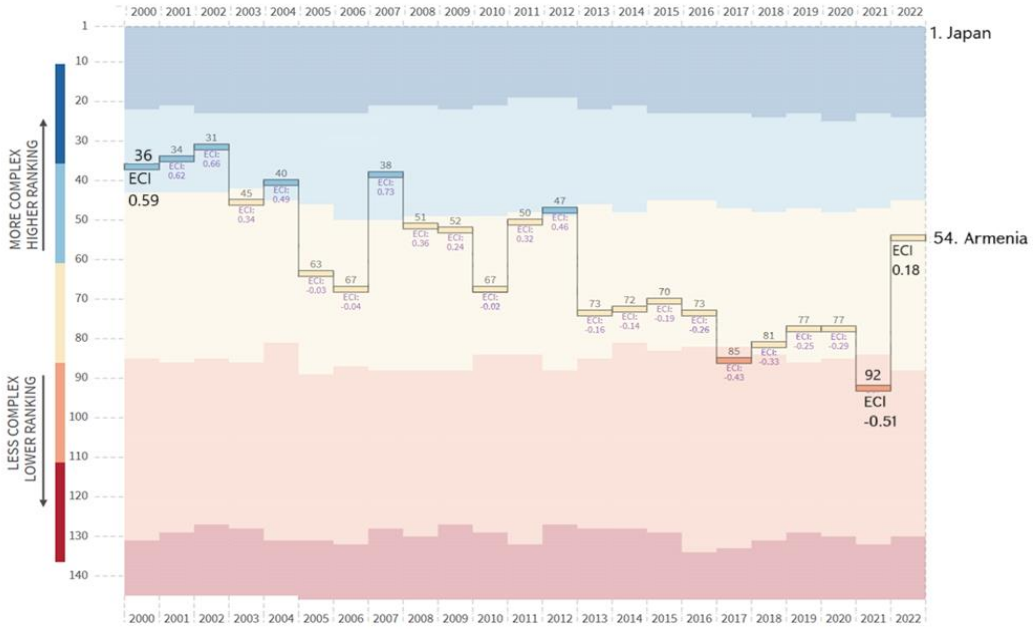

Figure 2. Economic Complexity Index of the Republic of Armenia, 2000-2022

Economic complexity reflects the amount of know-how embedded in the production structure of the economy, therefore there is a strong correlation between a country's ECI and their income per capita, as shown in Figure 3. It illustrates the relationship between the Economic Complexity Index (ECI-2021) and GDP per capita (2023) for the 134 countries. Hausmann, Hidalgo, et al. noted that "Countries whose economic complexity is greater than what we would expect, given their current level of income, tend to grow faster than those that are "too rich" for their current level of economic complexity".

The authors further note that countries a) below the regression line are often poised to enter periods of sustained growth because, if key constraints can be overcome, they can translate their existing stock of know-how into higher output and b) locations above the regression line may be in a more precarious position in terms of long-term growth as they may be benefitting from a temporary positive shock [Hausmann et al. 2013]. The chal-

lenge for the second group of countries is that if they do not use the boom to increase the complexity of their economies to a level consistent with their current level of income, they run the risk of having their level income fall toward the regression line after the boom ends.

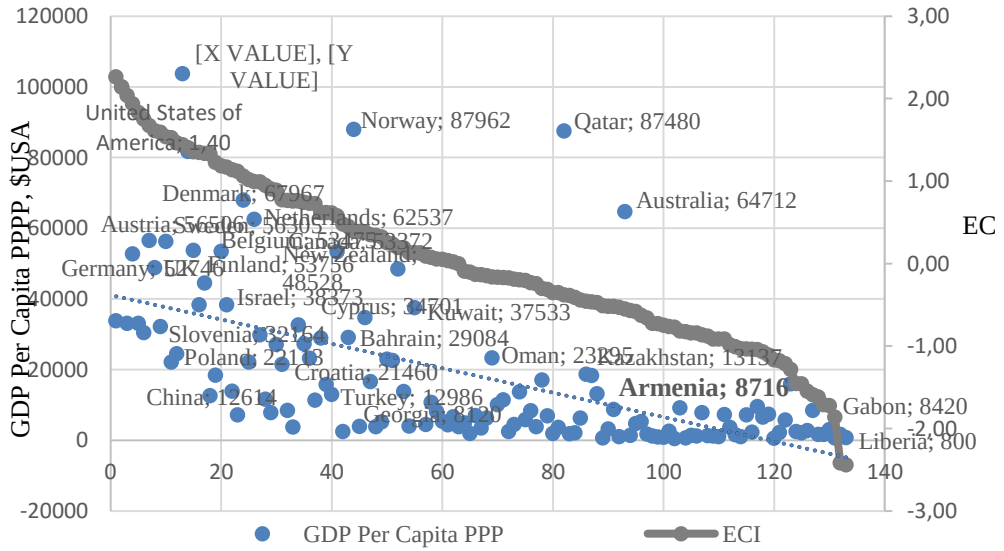

Figure 3. ECI (2021) & GDP Per Capita PPP (2023)
Source: Atlas of Economic Complexity and World Bank. WDI.

The implications for countries like Armenia that fall below the regression line are that:

- Many of these countries benefit from substantial resource wealth, while some also benefit from very strong institutions that reduce the negative impact of resource wealth, including boom-bust cycles.
- These countries may benefit from recognizing the risk inherent in resource wealth: long-term economic performance will be driven by an exogenously determined resource value, and it may be difficult to reallocate productive resources to alternative engines of growth;
- They often have difficulty sharing the benefits of resource wealth, since in many cases resource rents do not always translate into long-term material benefits for the locations where they were extracted.
- Countries endowed with natural resource wealth face challenges in diversifying employment opportunities that stem from the distorting macroeconomic effects that natural resources can have.

Ricardo Hausmann and Bailey Klinger [Hausmann & Klinger, 2006] introduced another important theoretical foundation of economic complexity and showed that the probability that a location develops the ability to produce a new product varies based on the set of

products that it already produces. This allowed for the measurement of the similarity between products based on their shared capabilities. Based on this pattern, they introduced a measure of proximity between products as the minimum conditional probability that they are co-exported by the same country. The collection of all product proximity pairs can be visualized in a network, known as the Product Space, and used to study the productive structure of locations. The structure of the Product Space and a location's position within it is crucial as it affects the ability of locations to move into new products. A highly connected position in the Product Space reflects relatively easier paths to diversification than a sparse position.

Hausmann and Klinger find that the Product Space is highly heterogeneous (some sections are composed of densely connected groups of products whereas others are more loosely connected): "For each commodity cluster, the average proximity is higher within commodity clusters than between them. Yet we also see that such a simplification hides great heterogeneity… It appears that while not unreasonable, simplifications of the product space mask a great deal of heterogeneity, which is not surprising given how varied production processes, and their required capabilities are" [Hausmann & Klinger, 2006]. This heterogeneity has significant implications for the speed and patterns with which structural transformation takes place, thus the ability of countries to diversify into products that are more complex is crucially dependent on their starting location in the Product Space. Product Space helps to define paths to diversify a country's economy based on the connectedness of its know-how. Harvard Growth Lab's research finds that countries tend to diversify by moving into nearby and related products or into those that require similar know-how to build on existing capabilities.

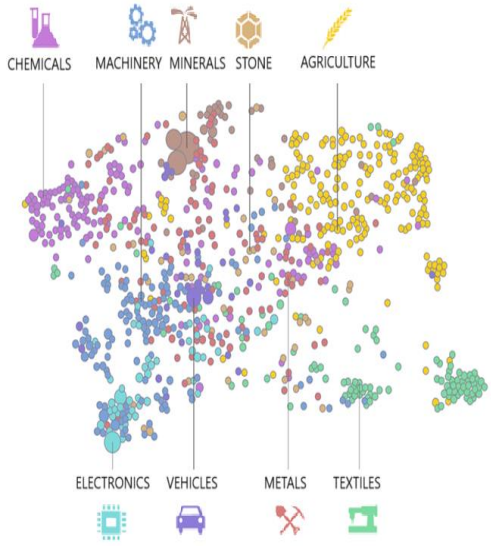

Figure 4. The complete Product Space, 2022

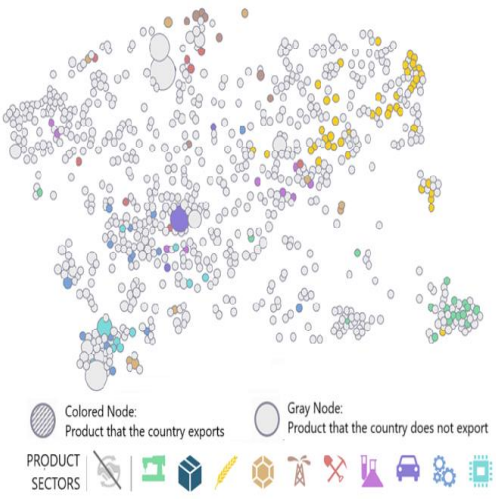

Figure 5. Armenia in the Product Space, 2022

Product Space represents the relatedness of over 800 goods using real-world data, as shown in figure 4[1]. Armenia's position in the Product Space is shown in Figure 5[2]. Countries are more successful in diversifying when they move into production that requires similar know-how and builds on existing capabilities. Armenia's Product Space illustrates the relatedness of its exports and potential paths to diversify its economy.

According to Harvard Growth Lab's estimates, "Armenia ranks as one of the most economically complex countries on the Growth Lab ECI ranking. In order to continue its growth, Armenia must promote innovation and invent new products"[3]. Regarding the first part of this conclusion and based on the assumption stated above, the economic complexity index of Armenia in 2022 is in no way connected with reality and can be defined as "pseudo-complexity". As for the second part of the mentioned conclusion, there is no doubt that the promotion of innovations is very relevant and vital for Armenia in order to significantly change the structure of exports in the direction of increasing the share of complex products in the total volume of exports. It should be noted that the economic complexity of a country is connected to the complexity of the products that it exports. The structure of Armenian exports for 2022 is shown in Figure 6.

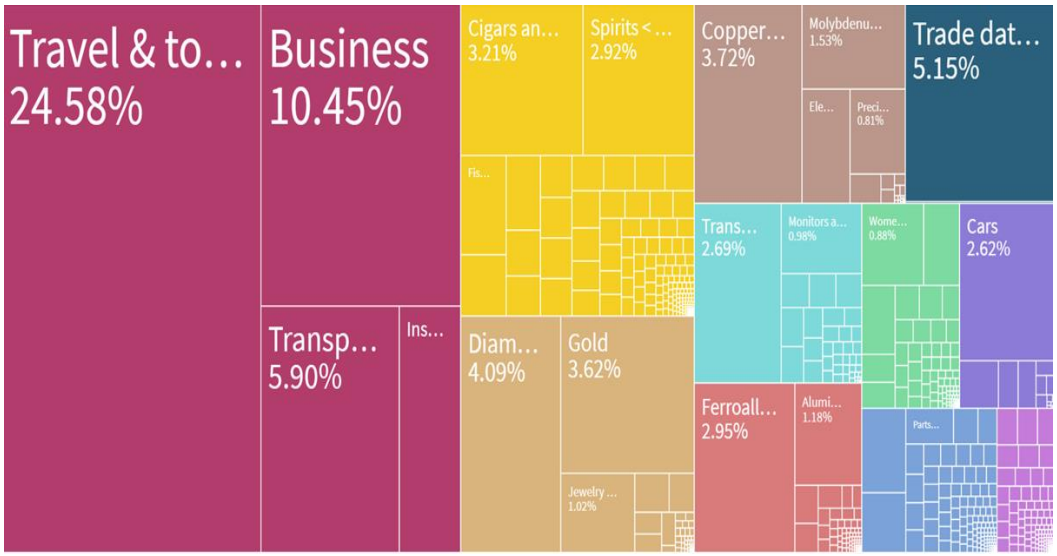

Figure 6. The structure of Armenian exports[4]

As shown in Figure 6 and table 3, a significant share is made up of products and services with a low Product Complexity Index value.

[1] Source: https://atlas.cid.harvard.edu/countries/9/product-space
[2] Source: https://atlas.cid.harvard.edu/countries/9/paths
[3] Source: https://atlas.hks.harvard.edu/countries/51/product-table
[4] Source: https://atlas.hks.harvard.edu/explore/treemap?exporter=country-51

Table 3. Five most complex and five the least complex products

Product Code (SITC4)	Prodact Name	Product Community	Product Complexity Index
Top 5 Product by Comlexity			
7284	Machines & appliances for specialized particular industries	Machinery	2.27
8744	Instrument & appliances for physical or chemical analysis	Chemicals & Health	2.21
7742	Appliances based on the use of X-rays or radiation	Chemicals & Health	2.16
3345	Lubricating petrol oils & other heavy petrol oils	Chemicals & Health	2.10
7367	Other machine tools for working metal or metal carbide	Machinery	2.05
Bottom 5 Product by Complexity			
3330	Crude oil	Oil	-3.00
2876	Tin ores & concentrates	Mining	-2.63
2631	Cotton, not carded or combed	Cotton, Rice, Soy & Others	-2.63
3345	Cocoa beans	Tropical Agriculture	-2.61
7367	Sesame seeds	Cotton, Rice, Soy & Others	-2.58

Source: https://www.businessinsider.com/atlas-of-economic-complexity-2011-10?op=1

In this regard, the Harvard Growth Lab notes that "Armenia's existing know-how affords a moderate amount of opportunities to diversify into related products". For diversifying economy, recommended follow strategic approaches: 1) *Light Touch Approach*; 2) *Parsimonious Industrial Policy Approach;* 3) *Strategic Bets Approach;* 4) *Technological Frontier Approach* (see Figure 7).

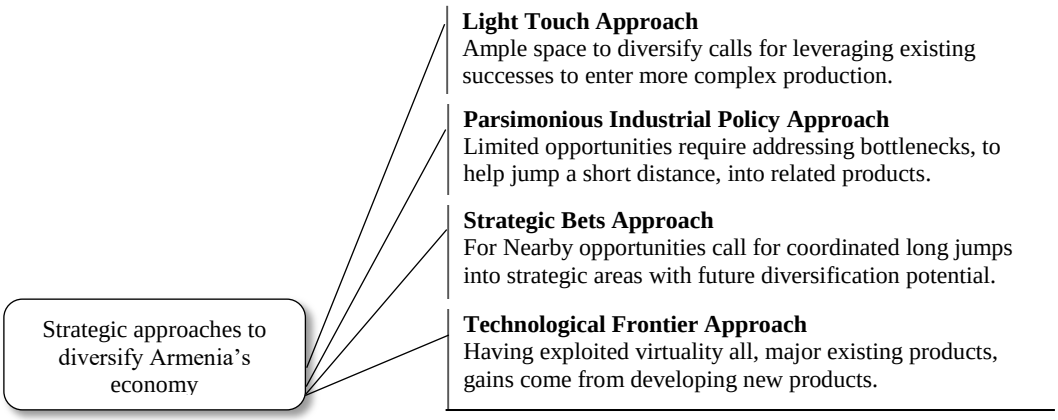

Figure 7. Strategic approaches to diversify Armenia's economy[1]

Algorithms for the formation of a strategy for diversifying the Armenian economy based on the above strategic approaches are presented in the figure 8.

1 Constructed by the author based on the source: https://atlas.hks.harvard.edu/countries/51/strategic

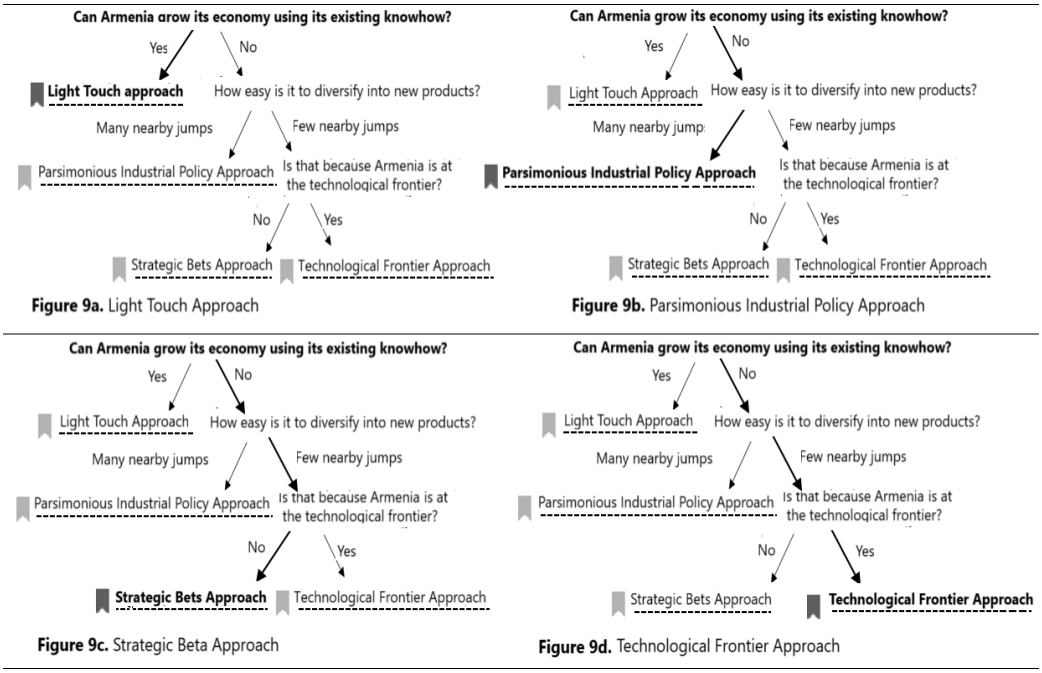

Figure 8. Algorithms for forming a strategy for diversifying the Armenian economy

Countries grow by diversifying into new products of increasing complexity. Strategic new products aim to balance:

- Distance to existing capabilities: lower distance (close to 0) signifies a product is "nearby" to existing know-how.
- Complexity: more complex products tend to support higher wages.
- Opportunity gain for future diversification: higher values hold more linkages to other high-complexity products, opening more opportunities for continued diversification.

Armenia ranks as one of the most economically complex countries on the Growth Lab's ECI ranking. In order to continue its growth, Armenia must promote innovation and invent new products. The Technological Frontier Approach appears to be a viable strategic approach to increasing the degree of Armenia's economic complexity.

Based on the results of numerous empirical studies, Peter Howitt and David Mayer-Foulkes conclude that the "large income differences that have emerged are mainly explained by differences in productivity rather than by differences in education and capital accumulation caused by neoclassical growth theory" [Howitt et al., 2005], thus arguing from the perspective of complexity economics. However, the authors see a major problem facing any technological explanation of divergence. Specifically, many studies show that a large group of countries have been converging to parallel growth paths over the past 50 years or so. The tendency for convergence among rich countries is easy to under-

stand as a manifestation of technology transfer. From this, the authors ask the following questions: 1) But what force has counteracted technology transfer to produce the technological divergence that has occurred over a longer period since the mid-19th century? 2) And why did this force stop working in the second half of the 20th century? Moreover, this modern convergence group does not include, in particular, the post-Soviet countries, including Armenia, as well as many other countries, as a result of which the gap between the leading countries as a whole and the poorest countries as a whole continued to widen throughout the second half of the 20th century, as shown by the Frontier Technology Readiness Index

Table 4. Readiness for Frontier Technology Index (2022) by Top 10 Countries and Selected Groups[1]

Top 10 Countries and Selected Groups		Scores
Top 10 Countries in Ranking		*Total score*
1.	United States of America	1.0
2.	Sweden	0.99
3.	Singapore	0.96
4.	Switzerland, Liechtenstein	0.94
5.	Netherlands	0.94
6.	Republic of Korea	0.94
7.	Germany	0.92
8.	Finland	0.92
9.	China, Hong Kong SAR	0.91
10.	Belgium	0.91
Average score:		0.94
Selected Groups		*Average score*
1.	Small Island Developing States (SIDS)	0.37
2.	Landlocked Developing Countries (LLDCs), including:	0.29
2.1.	Armenia	0.51 (Total score)
3.	Sub-Saharan Africa	0.23
4.	Least Developed Countries (LDCs)	0.19

As shown in the table 4, the difference between the average score of the top 10 countries and average scores the selected groups ranges from 2.5 to 5 times. Peter Howitt and David Mayer-Foulkes raise another question about why the forces that ended the divergence between middle - and high-income countries have not ended the divergence between very rich and very poor countries. The authors then set the goal how these questions can be addressed by modern Schumpeterian growth theory. To achieve this goal, Peter Howitt and David Mayer-Foulkes propose a model of economic growth based on the multi-country model of Howitt [Howitt, 2000], which in turn is an extension of the Aghion-

[1] Compiled by the author based on the source: UNCTAD, "Technology and Innovation Report 2023: Opening Green Windows - Technological Opportunities for a Low-Carbon World", pp. 154-167.

Howitt [Aghion & Howitt, 1992] model of growth through creative destruction, which implies a particular form of club-convergence. "Specifically, in the earlier multi-country model all countries that continue to invest in new technologies eventually grow at the same rate, because they draw ideas from each other, whereas countries that do not invest in new technologies stagnate because without making technology investments of their own they cannot benefit from technology transfer" [Howitt & Mayer-Foulkes, 2005]. In this regard, Robert Evenson and Larry Westphal argue, that "a country cannot keep up with the frontier merely by copying technologies developed in leading countries, because technological knowledge is often tacit and circumstantially sensitive" [Evenson & Westphal, 1995]. The problem, therefore, is to provide workers with productive knowledge that will correspond to the current technological frontier. In Armenia, perhaps, some progress has been made in the field of information technologies, which is necessary, but not sufficient from the point of view of increasing country's economic complexity degree. The proof of this is the low efficiency of technological investments in the Republic of Armenia in the previous three decades, the indicator of which is the country's Frontier Technology Readiness Index.

In order to achieve the goal set by the program of the Government of the Republic of Armenia for 2021-2026, at least three important issues need to be addressed to achieve the set guidelines: (1) increasing the level of product complexity in existing or potential sectors, (2) ensuring the country's involvement in international technology transfer processes by promoting FDI in selected sectors, (3) increasing the level of domestic savings [Vardanyan & Vardanyan, 2022]. In this context a particularly important conclusion has been made by the Commission on Growth and Development in the Growth Report 2008: "…as growth depends on investment, investment depends on a country's ability to finance it – out of its own savings or from foreign sources. There are limits to the latter, however, because foreign borrowing is risky. These limits are not very precise. But when they are breached the consequences can be very costly as many debt crises remind us… there is no case of a sustained high investment path not backed up by high domestic savings". At the same time, the important aspect of foreign direct investment is noted in terms of knowledge transfer and advanced technologies: "In developing countries, FDI is a small fraction of total investment. But because of the knowledge transfer it normally carries with it; its importance is much larger than its fractional contribution to total investment"[1]. The conceptual basis for increasing the complexity of the economy through the introduction of advanced technologies was developed by the author of this article in co-authorship [Vardanyan & Vardanyan, 2022].

[1] The Growth Report: strategies for sustained growth and inclusive development. Washington, DC : World Bank, 2008, p. 42.

Conclusions

Overall, complexity theory goes far beyond traditional economic theory, and this theory improves our understanding of the complex phenomenon of economic development, which is especially important for economic policymakers in countries like Armenia. The analysis of the evolution of economic complexity in Armenia shows that adaptability to accelerating global changes and increasing uncertainty can be achieved by increasing the degree of economic complexity of the country's economies.

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Economic complexity theory and its applications: a case study of Armenia

Key words: complexity economics, economic complexity, economic complexity index, fragile states index, product space, frontier technology, export, economic development

Complexity economics, a relatively new paradigm, is a new approach to economics, originating from the Santa Fe Institute in the late 1980s that uses models from complexity theory to view and model the economy as a complex adaptive system. This paradigm arose in response to the limitations of standard economic theory, which struggled to explain many phenomena in the post-industrial era. This article provides a brief overview of the field of complexity economics, highlighting some of its main characteristics and how it differs from the traditional approach. Economic complexity expresses a country's overall productive capabilities through its cumulative know-how, skills, and technological endowment. It is, therefore, a useful indicator to track structural change. As one of the applications of complexity economics the economic complexity index of a country is considered and in this context - the evolution of Armenia's economic complexity. It was also revealed that the "Harvard Growth Lab" methodology does not cite the re-export factor, which distorts the actual state of a country's economic complexity resulting in pseudo-complexity metrics of the economies of some countries, including the case of Armenia in 2022: the jump in the economic complexity index compared to 2021 was 0.67, and in the ranking Armenia rose from the 91st horizontal to 54th place in one year. Taking into account the four strategic approaches to increasing product complexity and economic complexity of the country recommended by the "Harvard Growth Lab", as well as the results of other studies, the choice of frontier technology approach was justified.