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DYNAMICS OF THE ARMENIAN INNOVATION SYSTEM: A FUNCTIONS-BASED ANALYSIS IN CATCHING-UP CONTEXT

Master's thesis

Technology Governance and Sustainability Program

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Tallinn 2024

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The document length is 16804 words from the introduction to the end of the conclusion.

Leigha Schjelderup 29 DECEMBER 2024
(date)

TABLE OF CONTENTS

ABSTRACT

Innovation systems (IS) enable nations to navigate the challenges and opportunities of technological transformation. Although Armenia has identified high-tech development as a promising pathway for achieving economic resilience as it transitions from a centralized to market economy, structural weaknesses in the country's national innovation system (NIS) challenge this vision. This thesis investigates the dynamics of Armenia's emerging AI sector through the lens of the functions of technological innovation systems (TIS) framework, a processed-based approach better suited to transition context than the structure-oriented NIS model. Employing a qualitative methodology, the study leverages stakeholder interviews to evaluate the pattern and functionality of the emerging AI TIS and its potential to facilitate technological catch-up. The findings indicate that despite the sector's strategic potential, its growth is constrained by national fragmentation and underdeveloped institutional capacities. These results contribute to a more nuanced understanding of potential policy interventions and provide theoretical insights for adapting the functions of TIS framework to similar contexts.

Keywords: National Innovation Systems (NIS), Technological Innovation Systems (TIS), technological catch-up, transition economies, social capability, Artificial Intelligence (AI)

LIST OF ABBREVIATIONS

AI - Artificial Intelligence

ASOF - Armenian Society of Fellows

CARIN - Consolidate Armenia Research Fellowship

DARPA - Defense Advanced Research Projects Agency

EIF - Enterprise Incubator Foundation

FAST - Foundation for Armenian Science and Technology

GII - Global Innovation Index

GIF - Global Innovation Forum

GPU - Graphics Processing Unit

IS - Innovation Systems

LARIK - Launch Armenia Research Fellowship

LLM - Large Language Model

ML - Machine Learning

MIT - Massachusetts Institute of Technology

MoE - Ministry of Economy

MoESCS - Ministry of Education, Science, Culture and Sport

MoHTI - Ministry of High-Tech Industry

NSF - National Science Foundation

NCIE - National Center for Innovation and Entrepreneurship

NIS - National Innovation Systems

PM - Prime Minister

RA - Republic of Armenia

R&D - Research and Development

STCC - Science and Technology Convergence Conference

TIS - Technological Innovation Systems

UN - United Nations

USC - University of Southern California

VC - Venture Capital

YSU - Yerevan State University

INTRODUCTION

In their foundational work on evolutionary economics, Nelson and Winter (1982, p. 3) cautioned of the "promise and danger" characterizing economic policy. Four decades on, this duality remains relevant as nations attempt to navigate the increasingly complex stakes of technological transformation. In the face of mounting global challenges, innovation-based development is considered both a growth strategy and an existential "imperative" (OECD, 2015, p. 3).

This resonates deeply in post-Soviet Armenia, whose reality as a small, landlocked nation in the South Caucasus has constrained development efforts. Despite having ancient roots, Armenia’s modern history began relatively recently, with independence ostensibly achieved twice: in 1991 with the fall of the USSR and again in 2018 when a peaceful revolution catalyzed widespread democratic reform. Though this positive momentum was devastated in 2020 by the "dual shocks" of pandemic and war, Armenia emerged as the fastest-growing economy in Eastern Europe and Central Asia (*Overview*, n.d.). This achievement notwithstanding, the nation faces enduring uncertainty about its future in the contentious region.

It follows that Armenia has been well versed in the allusions of "promise and danger" in development discourse. Resource limitations, geopolitical instability, and an incontestable need for self-reliance have fueled the narrative that strengthening a high-tech innovation system (IS) is the key to realizing a resilient economy and safeguarding national security. While the initial decades after independence focused on transitioning from “survival” to development (Poghosyan, 2017, p. 59), the revolution catalyzed significant institutional reform, signaling a renewed commitment to delivering on long-held promises to build a competitive knowledge-based economy. Appeals to a legacy of scientific excellence as the former "Silicon Valley of the Soviet Union” (Khnkoyan, 2012, p. 78), combined with a modern surge of entrepreneurial culture, drive this vision. However, the extent to which intentions are realized aligns with Pavitt's characterization of system transition: "slow, messy, and disappointing" (1997, p. 43).

Research Problem

Reflecting its strategic “imperative,” Armenia's IS has been extensively evaluated (Khnkoyan, 2012; UNECE, 2014; Poghosyan, 2017; UNECE, 2023). The national innovation system (NIS) framework is often used to model and assess system performance, highlighting structural barriers common to post-Soviet transition economies (Dyker and Perrin, 1997, pp. 54-55).

Amidst these challenges, a cluster of high-tech excellence has developed within the "fragmented" NIS (Liu, 2009, p. 120). An influential 2020 World Bank report positioned Armenia's nascent Artificial Intelligence (AI) industry as an area with strategic potential (Onugha, 2020). As a relatively low capital-intensive field with significant growth opportunities, establishing a domestic stake in the global AI “revolution” is promoted by industry proponents as the most promising path to achieving national economic and security goals (Israyelyan, 2023).

The role of the state in facilitating technological catch-up is well established (Perez and Soete, 1988; Freeman, 2002; Fagerberg and Godinho, 2004), with proactive policy making even more indispensable in the new techno-economic paradigm (Perez, 2010). However, the emergence of a new technological system is a “long, uncertain and painful process” (Jacobsson and Johnson, 2000, p. 630). Despite an ostensible high-level commitment to realizing Armenia's "high-tech potential" (Onugha, 2020) AI advocates argue that supportive public sector rhetoric has yet to deliver the necessary reforms—not just for AI, but across the entire NIS. As the “window of opportunity” (Perez and Soete, 1988) for participating in the emerging technology system wanes, identifying and addressing system weaknesses becomes increasingly urgent.

Research Objectives

This thesis aims to explore IS dynamics in Armenia by applying the functions of technological innovation systems (TIS) framework (Hekkert et al., 2007) to the emerging AI TIS. In contrast to the NIS model’s traditional focus on structural components, the TIS approach offers a process-based lens to examine “what is achieved” (Jacobsson and Bergek, 2006, p. 703) in the system and to identify “weaknesses in functional terms” (Bergek et al., 2010, pp. 19-20). While some experts question the framework's applicability beyond the developed country context it was modeled on, TIS proponents argue that it should not only be adapted for diverse empirical cases but that these cases should also inform the model's ongoing reevaluation (Jacobsson and Bergek, 2006; Markard et al., 2015; Bergek et al., 2015). This thesis makes a contribution to this imperative by exploring how the structural-functional conditions for catching-up in emerging TIS in transition economy NIS can be better integrated within the framework.

Ultimately, the aim of tracing the pattern and functionality of the emerging AI TIS in Armenia is not to provide an objective evaluation of system performance. Instead, it seeks to shift the narrative from the "quasi-static" (Hekkert et al., 2007, p. 414) NIS lens to a more dynamic understanding of the TIS, primarily through the perspectives of actors involved in its development. Acknowledging that the "structural causes of functional weaknesses" often "reside" at the national level (Jacobsson and Bergek, 2011, p. 46), the evolving story of sector-specific development efforts in Armenia can contribute to discourse on issues affecting the system as a whole.

Drawing from NIS, TIS, catching-up, and transition economy literature, this thesis aims to explore two related research questions:

1. What elements of transition economy NIS are most relevant to technological catch-up in emerging TIS, and how can these structural-functional considerations be more effectively represented within Hekkert et al.'s (2007) framework?
2. Informed by the application of this adapted framework, what are the potential developments and challenges of the emerging Armenian AI TIS in functional terms, and how can these insights enhance understanding of broader NIS dynamics relevant to technological catch-up?

In order to address these questions, the thesis is organized as follows:

The first section reviews IS theory from national and technological perspectives, summarizing the primary structural-functional elements and functional pattern of participating in an emerging TIS. It then explores the role of IS in technological catch-up, particularly within the context of transition NIS, as well as how these considerations could be reflected in the TIS framework. The methodology outlines the application of this approach to the case study of Armenia's emerging AI TIS, employing a mixed, qualitative research design. The results section reviews the historical context and evolution of the Armenian NIS before analyzing AI system building efforts through stakeholder perspectives. These empirical findings help inform a broader discussion about NIS dynamics and catch-up capacity, concluding with a review of the theoretical takeaways and potential avenues for future research.

1. THEORETICAL FRAMEWORK

1.1. INNOVATION SYSTEMS (IS)

The IS framework emerged in the late 1980s to explain the dynamics of technological transformation and economic development (Sharif, 2006, p. 745). Grounded in an "evolutionary" approach, the model emphasizes the complexity and interdependence of system elements, and operates as both a "determinant of technological change" as well as a theoretical tool used to understand it (Hekkert et al., 2007, pp. 413-414). This section will review IS theory from both national and technological perspectives, examining the framework's role in guiding policy interventions across diverse contexts.

1.1.1. National Innovation Systems (NIS)

The NIS model was developed by evolutionary economists in response to the neoclassical disregard of the importance of innovation in economic growth (Freeman, 2003 cited in Sharif, 2006, p. 754), and has had a transformative impact on the way a country's development is understood and analyzed (Sharif, 2006; Edquist, 2006; Chaminade et al., 2018). Although subsequent theories would approach IS from a variety of lenses (local, regional, and sectoral) (Bergek et al., 2008, p. 408) each new iteration builds upon the NIS structural framework.

NIS are composed of actors interacting in networks under a common set of institutions, where organizations can be viewed as the "players of the game," and institutions the "rules they play by" (North, 1990 cited in Kitanovic, 2007, p. 31). While often attributed to entrepreneurs, NIS theory accounts for a wider variety of risk-taking agents influencing the innovation process, including the state (Chaminade et al., 2018). A core divide in NIS literature is whether to adopt a "narrow" or "broad" approach, the former including factors directly related to science and technological development and the latter encompassing the entire social system in which these elements are embedded and influenced (Lundvall et al., 2009, p. 2). Proponents of the "broad" view emphasize innovation as a collective process, resulting from knowledge flows and various types of "learning" within the system (Lundvall, 1992).

While there is no one definitive definition of NIS (Sharif, 2006), Freeman (1987) provides a simplified explanation as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies." This reference towards "activities" is important, as one common criticism of the NIS model is its primary focus on the structure of the system rather than investigating its actions limits the efficacy of policy interventions (Hekkert et al., 2007). Towards the end of the 20th century, the rapidly changing character, institutional demands, and increasing internationalization of new technologies inspired the formulation of a new, process-based frame of IS analysis: technological innovation systems (TIS).

1.1.2. Technological Innovation Systems (TIS)

Carlsson and Stakiewicz (1991, p. 111) first defined technological systems as "a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure…involved in the generation, diffusion, and utilization of technology." Despite significant overlap, they noted three key departures from the incumbent conceptualization of NIS: analysis is limited to one "techno-industrial" area, is both national and international in scope, and emphasizes "economic competence and knowledge networks…rather than institutional infrastructure" (Ibid., 112). They posit that these networks have the potential to form clusters that drive "development potential" within an otherwise low-functioning NIS (Ibid., p. 105).

The "functional" approach to TIS was created to identify and assess the activities influencing the innovation process, drawing primarily from the NIS model but incorporating insights from other domains such as sociology and political science (Bergek, 2019, pp. 1-2). It was developed through a joint initiative of scholars and policymakers in Sweden looking to improve the design and implementation of technology policies (Carlsson et al., 2010, p. 146 cited in Bergek, 2019, p. 1). They reiterate the evolutionary perspective, arguing that the market failure approach is an insufficient rationale for addressing system-level weaknesses through policy intervention (Metcalfe, 1994, p. 932; Carlsson and Jacobsson, 1997, p. 299; Bergek et al., 2010, p. 4; Jacobsson and Bergek, 2006, p. 690).

While NIS evaluations often assume a "quasi-static," narrow focus on structural failures, TIS proponents argue that they must be accompanied by a broader, dynamic "process focus" to increase their effectiveness (Bergek et al., 2008, p. 409). Hekkert et al. (2007) devised a list of seven core interrelated innovation processes and corresponding indicators that can be used to evaluate system performance (Figure 1).

FIGURE 1. FUNCTIONS OF INNOVATION SYSTEMS

	Function	Description	Indicators	Implications/interactions
F1	Entrepreneurial activities	Risk-taking/experimentation that turns potential of new knowledge, networks, and markets into opportunities	Active entrepreneurs/new entrants, diversification activities of incumbent actors, experiments with the new technology	IS success dependent on entrepreneurs; whose success is dependent on fulfillment of (F2-F7)
F2	Knowledge development	Generation of (technological) knowledge through "learning by searching" and "learning by doing"	R&D projects, patents, investments in R&D	Knowledge and learning mechanisms are at the heart of the innovation process
F3	Knowledge diffusion through networks	Networked exchange of R&D information between government, competitors, and broader market. "Learning by interacting," and "learning by using"	Workshops and conferences evoted to a specific technology topic, mapping the network size and intensity over time	Integral to aligning policy decisions with latest technological insights; affecting R&D agendas with changing norms and values
F4	Guidance of the search	Activities of industry, government, and/or market that positively affect the visibility/clarity of (and allocate limited resources towards) wants among technology users	Specific targets set by government or industry, academic articles / press that raise expectations, "success stories"	Influences the direction of technological change through guiding the learning process (F2 and F3)
F5	Market formation	Creation of protective space / temporary comparative advantages for emerging technologies	Temporary niche markets for specific technological applications, favorable tax regimes	Needed to overcome challenges with initial inefficiencies and resulting slow diffusion/adoption, product of (F2-F4)

F6	Resource mobilization	Both financial and human capital allocation to IS activities	Challenging to map through indicators, must interview stakeholders to determine whether main actors believe there is sufficient access to resources	Instrumental to knowledge development (F2)
F7	Creation of legitimacy / counteract resistance to change	Incumbent interests/regimes' opposition to "creative destruction" must be overcome through advocacy coalitions that legitimize the change	Rise and growth of advocacy coalitions and their lobbying efforts	Scale and success depends on available resources (F6) and future expectations (F4) about new technology
Source: adapted from Hekkert et al. (2007, pp. 421-425)				

1.1.2.1. Functions of Emerging TIS

While the TIS framework was originally developed to study sustainable technologies, it has since been applied to a wide range of emerging technological systems (Bergek, 2019, p. 17). Although the idiosyncrasies of different technological products and knowledge bases necessitate adaptations of the model, research supports its applicability across diverse cases (Markard et al., 2015). Artificial Intelligence (AI), for instance, represents a rapidly evolving global sector with an emphasis on algorithmic development and data-based applications over hardware innovations (Apell and Eriksson, 2023, p. 180). Existing applications of the TIS framework to AI (Apell and Eriksson, 2023; Alhosani and Alhashmi, 2024) affirm the relevance of the model for these contexts, however suggest that further refinement tailored to the specific characteristics of individual systems could enhance the utility of policy interventions.

Nevertheless, the existing TIS framework provides a valuable lens for analyzing the emergence of new TIS. As the process is inherently non-linear, advancing through "waves" (Freeman, 2002, p. 203), it is crucial for countries seeking to participate in emerging systems recognize their strategic potential and identify "windows of opportunity" to actively shape early development (Perez and Soete, 1988, p. 460). Perez and Soete (1988, pp. 477-78) contend that this process is contingent on three factors: the "capacity to recognize [new opportunities and favorable conditions], the competence and imagination to design an adequate strategy, and the social conditions and political will to carry it through." Each of these capacities—shaped by the interactions of actors, networks, and institutions within the national system—can be functionally represented within Hekkert et al.'s (2007) framework to illustrate the general development trajectory of an emerging TIS.

Actors' capacity to recognize new opportunities and favorable conditions is the instrumental first stage of participating in an emerging TIS. This ability largely stems from **entrepreneurial activities (F1)** from a variety of risk-taking agents, raising awareness and **guiding the direction of the search (F4)** toward areas with development potential—particularly in the "research, design, and development" (Freeman 2002, p. 210) of "information-intensive" sectors (Perez and Soete, 1988, p. 477). This capacity does not "fall from heaven" but instead is a product of a country's "previous history of development, natural resources, and social, cultural, and political factors" (Perez and Soete, 1988, p. 477). Identifying national conditions that align with international growth potential is essential for creating incentives that promote innovation (Edquist and Johnson, 2000, p. 53; Kitanovic, 2007, p. 33). Governments play a crucial role in this process, acting as coordinators in areas where market forces alone may not be sufficient in nurturing nascent sectors (Carlsson and Jacobsson, 1997, p. 306).

The next step towards realizing technological opportunity concerns ***network competence and imagination to design an effective strategy*** for **resource mobilization (F6)** to support **knowledge development (F2)** and **diffusion (F3)**. Timing and the nature of market entry are critical to a firm's competitive edge, especially for those positioning as "early imitators or innovators" rather than merely adopting existing technologies (Perez and Soete, 1988, p. 459). Smaller and newer firms, often founded by entrepreneurs with specialized academic backgrounds, play a crucial role in pioneering new systems by drawing on public knowledge typically provided by universities in the early stages of the technology (Ibid., pp. 467, 476). During this early phase, innovators may enter with "little capital and experience but relevant scientific and technical knowledge" (Ibid., p. 474). However, addressing "externalities" like geographical and cultural distance from knowledge sources is essential, as is creating mechanisms for knowledge "absorption" from the global system (Blum et al., 2015 cited in Bergek, 2019, pp. 16-17).

Lastly, the ***institutional conditions and political will necessary to implement these strategies*** is contingent on **legitimization and counteracting resistance to change (F7)**. The most significant barrier to this process is combating "organizational inertia," the absence of market-driven "pressure and directionality" in public institutions more conditioned to maintaining the status quo than supporting emerging sectors (Perez, 2010, pp. 198-199). Perez (2010, pp. 198-199) notes that institutions can become "outdated and inefficient," requiring cycles of "unlearning, learning, and relearning" to overcome the "old ways of doing things" that act as "dead weight" on innovation (Perez and Soete, 1988, p. 466). While this happens naturally in the private sector, it often requires outside pressure on public institutions to adapt (Ibid., p. 199). The rapid evolution of ICT requires even more robust "change-inducing mechanisms" to counter the intensifying resistance to new technological systems (Perez, 2010, p. 199; Kitanovic, 2007, p. 29). Carlsson and Jacobsson (1997, p. 304) argue that this is "by far the most important but also most difficult task for public policy."

It is important to note that one of Hekkert's (2007) key functions, **market formation (F5),** is excluded from the framework. The analysis focuses on the functions critical to building the system's foundation for knowledge development to participate in the existing international market, with domestic market development becoming more important as the TIS matures.

1.1.3. Assessing Framework Applicability

One core limitation of the IS approach is that it is primarily modeled after developed countries (Sharif, 2006, p. 760). As the functions of TIS were designed as a policy tool, more recent efforts have sought to adapt the model to a broader range of contexts, particularly developing countries (Bergek et al., 2015). Although "integrating normativity into TIS studies" is often contested (Markard, 2015, p. 82), the high stakes of failing to address development challenges underscores the urgency of critically engaging with systemic issues and opportunities.

While adapting the framework enhances the understanding of diverse empirical cases, IS research suggests that each country's unique historical context requires individual consideration (Freeman, 2002; Fagerberg and Godinho, 2002). The following section will explore a critical developmental context—technological catch-up in transition economies—focusing on the structural-functional considerations of “fragmented” NIS striving to engage in the development of emerging technologies during key “windows of opportunity” (Perez and Soete, 1988).

1.2 IS IN CATCHING-UP CONTEXT

Linked closely with development economics (Lundvall et al., 2009, p. 1), IS theory emerged as a framework to investigate the differences in growth rates between nations. Success stories of radical development in the mid 20th century are accounted for by Abramovitz’ (1986, p. 386) “catch-up” hypothesis, which posited that nations with low levels of technological productivity have the potential for rapid economic growth. Freeman’s (1987) foundational work on NIS was developed to explore a famous case of “catching up,” attributing Japan’s post-WWII development to science and technology strategy. The “East Asian Miracle” countries of Hong Kong, Singapore, South Korea, and Taiwan, are other former “technologically backwards” (Abramovitz, 1986, p. 388) nations that developed through effective industrial policy interventions (Freeman, 2002).

These cases demonstrate that catch-up is not a “spontaneous” occurrence, but rather a product of strategic public and private intervention (Freeman, 2002, p. 203; Pavitt, 1997, p. 58). As such, understanding how to effectively cultivate or intervene in IS conducive to rapid technological growth emerged as a policy focus (Sharif, 2006). While international development organizations endeavored to operationalize NIS frameworks to identify "best practices" (Chaminade et al., 2018, p. 23), efforts to measure or "benchmark" innovation proved challenging (Ibid., p. 78). One source of this complexity is “social capability,” the collective factors that determine a nation’s ability to “exploit emerging technological opportunity” (Abramovitz, 1986, p. 387). Though conceding its ambiguity and difficulty to measure, Abramovitz (Ibid., p. 388) advocated that the catch-up hypothesis must account for this facet, as “a country’s potential for rapid growth is strong not when it is backward without qualification, but rather when it is technologically backward but socially advanced.” A key aspect of "social capability," he posits, is institutional adaptability—the ability to respond to evolving technological opportunities (Ibid., pp. 388-89).

Despite efforts to identify universal best practices, Fagerberg and Godinho (2002, p. 537) argue that no single path to successful catch-up exists. To help empower nations chart their own path, Freeman (2002, p. 208) argues one must "put history back in economics."

1.2.1. Transition NIS

One group of developing countries that share a similar "social history" (Abramovitz, 1986, p. 406) affecting their capacity for technological catch-up are transition economies—those shifting from centrally-planned to market-oriented systems following the dissolution of the Soviet Union (Kitanovic, 2007, p. 36). While each case is shaped by specific historical path dependencies (Radosevic, 1999, p. 281), transition countries face common challenges in developing an IS (Dyker and Perrin, 1997). Transition literature emphasizes the "social" nature of this process—driven collectively by people, institutions, and their interactions (Dyker and Perrin, 1997, p. 7; Radosevic, 1999, p. 280; Kitanovic, 2007, p. 30). This perspective offers insights into the challenges of developing the "social capabilities" needed to foster innovation and enable technological catch-up with more advanced economies.

While development can follow various trajectories, the formation of new IS is often linked to "three structural processes: entry of firms and other organizations, formulation of networks, and institutional alignment" (Johnsson and Bergek, 2006, p. 689). In transition contexts, these factors are complicated by fragmentation and change-resistance of previously centralized systems (Dyker and Perrin, 1997, pp. 11-12). Addressing fragmentation requires building networks that support knowledge sharing and network coordination among system actors (Dyker and Perrin, 1997, p. 11), as well as links with international actors and markets (Kitanovic 2007, p. 31; Dyker and Perrin, 1997, p. 15). Given that much knowledge is embedded within individuals and organizations, establishing the "know-who" (Kitanovic, 2007, pp. 39-40)—facilitated by both formal and informal networking (Carlsson and Jacobsson, 1997, p. 301)—is essential for strengthening a country's "social capability."

Radosevic (1999, p. 278) emphasizes that transition NIS depends on the activity of "network organizers"—actors with the capacity and resources to drive coordination efforts. Ultimately, the goal of network organizers is to counteract "negative learning" characteristic of incumbent systems (Dyker and Perrin, 1997, p. 6), a form of "low-end forgetting" where critical knowledge or skills that are essential for innovation are neglected or lost due to an over-reliance on outdated practices (Kitanovic, 2007, p. 41). Kitanovic (Ibid., p. 32) argues that this can be mitigated through "creative forgetting" of old routines and the adoption, or "routinization," of new institutional approaches conducive to technological change (Ibid., p. 42).

The legacies of transition have a "dual nature," serving as both a creative "resource" and a "constraint" (Radosevic, 1999, p. 280). However, the conditions necessary for technological catch-up are becoming increasingly stringent, especially in light of rapid developments in new systems (Fagerberg and Godinho, 2002, p. 535). In fragmented NIS innovation can operate at "two speeds," where "clusters of development potential" exist within a weak national system (Carlsson and Stankiewicz, 1991, p. 111). While the NIS framework has been valuable for exploring the relationship between technical and institutional change and the conditions for "success" (Radosevic, 1999, pp. 279, 281), understanding the dynamics of emerging TIS is crucial for countries looking to participate in their development as a means of catching-up. The following section examines the policy imperatives driving the process.

1.2.3. Policy Intervention

Literature on catch-up, transition, and emerging TIS underscores the critical role of proactive policy making in addressing system failures that impede technological development (Carlsson and Jacobsson, 1997, p. 301). The state must articulate "clearly defined objectives" (Pavitt, 1997, p. 55; Dyker and Perrin, 1997, p. 8) in promising sectors where market forces have yet to materialize—"[embedding] private initiative in a framework of public action" (Rodrik, 2004, p. 1 cited in Jacobsson and Bergek, 2006, p. 688). Achieving this requires a process of "trial and error" (Radosevic, 1999, p. 313), indicating that nations aspiring to technological advancement must be prepared to tolerate failure. While common factors exist across cases, each country's policy approach must be "framed within the context of that unique institutional structure"—particularly in relation fragmentation (Dyker and Perrin, 1997, p. 10).

Although transition economies face pervasive challenges in overcoming system fragmentation, there are "windows of opportunity" to escape the cycle by fostering a domestic role in emerging international technological systems (Perez and Soete, 1988, p. 459). However, these efforts are often plagued by a conundrum where developing “high-level capabilities” conducive to IS development requires such capacities to begin with (Jacobsson and Bergek, 2006, p. 703). This “paradoxical” (Perez and Soete, 1988, p. 459) relationship complicates technological development, as Dyker and Perrin (1997, p. 10) argue that institutional reform is more likely to “induce” innovation than vice versa. While targeted public-private initiatives can eventually break this “vicious circle” (Dyker and Perrin, 1997, p. 12; Perez and Soete, 1988, p. 459), success remains “exceptional rather than inevitable” (Perez and Soete, 1988, p. 463).

In a transition context, these challenges intensify, as “exceptional” competencies can become “obsolete” during the shift from all-planning to “no planning” (Pavitt, 1997, pp. 54-55). Since networking is an effective remedy against fragmentation, policy should help provide the necessary resources to expand them (Dyker and Perrin, 1997, p. 11; Radosevic, 2002, p. 93). Although the cost of collaboration may pose challenges, achieving consensus can lead to collective learning (Radosevic, 2002, p. 92) and potentially the formation of a “collective identity” conducive to a well-functioning system (Saxenian, 1994 cited in Carlsson and Jacobsson, 1997, p. 302). Jacobsson and Bergek (2006, p. 702) note that the government can facilitate this coordination in emerging IS by establishing platforms for experience exchange and collaborative activity.

Dyker and Perrin (1997, p. 10) caution that nations “aiming to articulate a policy stance in relation to innovation will ignore the national system of innovation at their peril.” This thesis argues that the same principle applies to the functions of TIS, which provides a complementary framework for understanding the dynamic processes of technological and institutional change while identifying systemic challenges at the national level. Radosevic (1999) and Kitanovic (2007, p. 34) contend that transition context requires a shift from a structure-based to a process-based IS approach, emphasizing the importance of networked knowledge development within the system (Kitanovic, 2007, p. 43). This underscores the value of the functions-based TIS model, which is better suited for capturing the dynamics of IS in transition. By tracing system development through a functional lens, the model helps illuminate the "structural causes of functional weaknesses" rooted at the national level (Jacobsson and Bergek, 2011, p. 46).

The following section leverages these theoretical findings to address the first research question: how can the structural-functional considerations of transition NIS, focused on catching up through the development of emerging TIS, be integrated within Hekkert et al.'s (2007) framework to better analyze IS-building efforts in these contexts?

1.3. FUNCTIONS OF EMERGING TIS IN TRANSITION NIS CONTEXT

Jacobsson and Bergek (2006, p. 703) highlight the utility of the functional framework in catch-up contexts, describing its dual role as both a tool for retrospective analysis and a method for identifying system weaknesses in real time. While the conventional approach outlined by them and Hekkert et al. (2007) (Figure 1) is relevant across all IS, the dynamics of transition NIS suggest that certain factors warrant more explicit consideration when applying the model in these contexts. The functional pattern of participating in emerging TIS (Figure 2) provides a valuable platform for tracing efforts to develop an emerging TIS. These insights support the identification of system dynamics necessary for addressing structural barriers in transition economies and facilitating catch-up through emerging technologies.

FIGURE 2. FUNCTIONS OF EMERGING TIS IN TRANSITION NIS CONTEXT

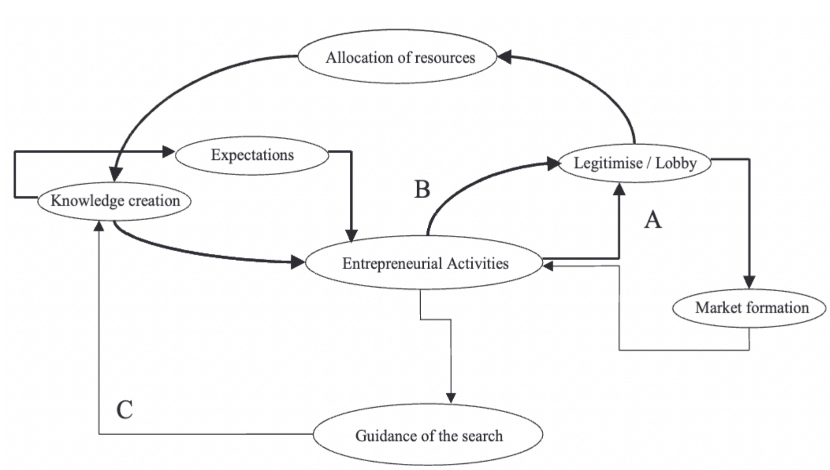
Actor capacity to recognize new opportunities and favorable conditions	F1 F4	Entrepreneurial activities Guidance of the search	Entrepreneurial risk-taking that transforms new knowledge and networks into opportunities, particularly in emerging technological sectors during key "windows of opportunity" (Freeman, 2002; Perez and Soete, 1988). This ability is shaped by a nation's social and political context, (Edquist and Johnson, 2000; Kitanovic, 2007), where proactive government coordination and experimentation is also crucial in fostering emerging sectors where market forces may not yet exist (Carlsson and Jacobsson, 1997).
Network competence and imagination to design an effective strategy	F6 F2 F3	Resource mobilization Knowledge development Knowledge diffusion through networks	Realizing technological opportunity requires effective resource allocation for knowledge development and diffusion. Timing is crucial for early innovators: smaller firms often lead in new technology using publicly-available knowledge, but depend on "know-who" as systems become progressively closed (Perez and Soete, 1988, pp. 459, 467, 476). Addressing geographical barriers and enhancing international knowledge absorptive capacity is an essential target of public policy (Ibid.).
Institutional conditions and political will to carry it through	F7	Creation of legitimacy / counteract resistance to change	Organizational inertia in public institutions hinders innovation by favoring outdated practices. Institutions must engage in "creative forgetting" (Kitanovic 2007, 42) —cycles of"unlearning" and "relearning"—in order to meet evolving technological demands (Perez, 2010, pp. 198-199).

The following sections will examine how tracing this functional pattern can serve as a "focusing device" (Jacobsson and Bergek, 2006, p. 703) for understanding the dynamics of an emerging system, as well as the factors that must be considered when assessing its "functionality" in enabling technological catch-up.

1.3.1. Functional Pattern

The most critical demand on emerging TIS aiming to overcome the "organizational inertia" (Perez and Soete, 2010, p. 198) endemic to transition NIS is **legitimization and counteracting resistance to change (F7)**. Hekkert et al. (2007) identify this function as a primary catalyst or "[trigger]" (Jacobsson and Bergek, 2006, p. 700) for "virtuous cycles" or "motors of change" in IS development (Figure 3), as "entrepreneurs [lobby] for better economic conditions to make further technology development possible" (2007, p. 426). "Motor B" illustrates this process by tracing the sequence of **entrepreneurial activities (F1)** that seek to **legitimize and advocate (F4, F7)** for specific **resource mobilization (F6)** directed towards further **knowledge development (F2, F3)** within an emerging TIS.

FIGURE 3. MOTORS OF CHANGE



Source: Hekkert et al. (2007, p. 426)

System building depends not on individual functions operating in isolation, but rather their interactions over time (Hekkert et al., 2007, pp. 425-426). As an inherently a "collective" process, three critical considerations face system actors: which functions to perform independently, which to undertake collaboratively, and which to compete for (Van de Ven, 1993, cited in Hekkert et al., 2007, p. 422). Ultimately, the success of a TIS is primarily determined by the degree of "alignment" on these functions (Carlsson and Jacobsson, 1997, p. 301). A helpful mechanism to explore these dynamics in a transition context is through the activities of "network organizers" (Radosevic, 2002, p. 87). Jacobsson and Bergek (2006, p. 689) emphasize that they typically include learning networks and advocacy coalitions, which together help consolidate resources and "[give] the collective a voice in the political arena." Both Hekkert et al. (2007, p. 426) and Jacobsson and Bergek (2006, p. 703) suggest that research into these patterns of change could provide valuable insights into how momentum is built—or impeded—in developing a new system.

The issue of alignment underscores that system-building efforts are not always "virtuous." Functions can also be fulfilled negatively—often due to a lack of coordination and consensus among network organizers—and can lead to "vicious cycles" that undermine collective progress (Hekkert et al. 2007, p. 427). Consequently, assessing the "functionality" of TIS development—especially in the context of catching up in transition economy NIS—requires a nuanced understanding of the conditions driving both characters of cycles. These factors reveal the immediate broader system challenges and provide insight into the interventions necessary for mitigating them.

1.3.2. Assessing Functionality

In addition to alignment, this thesis argues that in a catching-up transition context, assessing the success or "virtuosity" of the functional pattern captured by "motor B" hinges on an expanded understanding of **legitimization and counteracting resistance to change (F7).**

First, the concept of legitimacy of an emerging TIS should encompass the policies and political processes behind its development. For the former, the legitimacy of government action—"whether and how to support a technology by public policy" (Markard et al., 2015, p. 81)—must reflect the extent to which it promises "economic benefits to the population" (Radosevic, 1999, p. 278). This factor is "crucial for the survival and effectiveness" of policies (Carlsson and Stankiewicz, 1991, p. 109). Equally important, however, is "getting the policy process right" (Rodrik, 2004, p. 3), influenced by context-specific factors such as navigating conflicts between asymmetric "incentive" (Pavitt, 1997, p. 45) and "power" structures (Dyker and Perrin, 1997, p. 10). Establishing the necessary "institutional mechanisms" to support stakeholder alignment and effective policy implementation is a costly and ongoing process (Kitanovic, 2007, p. 29) that can be further complicated by institutional uncertainty and coordination failures, leading to rivalries among competing interests (Radosevic, 1999, p. 290). While the functional framework lacks an explicit focus on politics (Bergek et al., 2015), Kern (2015, cited in Markard, 2015) argues that it is indispensable to understanding TIS dynamics as "struggles over the right course of action and who gets what and when" are fundamental to innovation and transition processes (Grin, 2010, cited in Markard et al., 2015, p. 81).

A second related consideration is a need to develop institutional adaptive capacity as part of counteracting resistance to change, an aspect not fully reflected in existing functional approaches (Markard et al., 2015, p. 81) but indispensable to catching up in transition NIS. Abramovitz's (1987, p. 388) hypothesis posits that technological advancement is possible when a country is "technologically backward but socially advanced." In a fragmented NIS where individual technological clusters may be "advanced" but operate within a socially "backward" system, efforts must focus on building the "social capability for technical and institutional change" at the national level (Freeman, 2002, p. 203). As Kitanovic (2007, pp. 32, 42), this hinges on the capacity for institutions to "creatively forget" outdated routines while learning and "remembering" ones more conducive to evolving technological demands.

Ultimately, in transition NIS context, this thesis proposes that the "functionality" of TIS-building efforts should not be judged solely by developments within the individual sector. Instead, "virtuosity" should be gauged by the extent to which functional patterns contribute to building the “social capabilities” necessary to counteract “vicious cycles” of fragmentation at the national level. Without a focus on addressing these structural limitations, sector-level developments risk becoming isolated interventions rather than genuine IS-building initiatives, leading to repeated cycles of “reinventing the wheel” (Radosevic, 1999, p. 284) and undermining the long-term potential for technological catch-up.

1.3.3. Adapting IS for Technological Catch-up

Despite the efficacy of NIS in modeling innovation dynamics in developed economies, the structure-level interventions it enables are less suited for developing countries where the NIS is not fully functional. This applies especially in transition economies, where the NIS faces pervasive structural issues such as fragmentation. By focusing on functions, the TIS approach is comparatively better-suited for nations seeking to capitalize on “windows of opportunity” in the development of emerging technologies as a pathway to catching up.

A review of catch-up, transition, and emerging TIS literature helped inform an adapted approach to Hekkert et al.’s (2007) functions of TIS framework (Figure 2), highlighting the importance of proactive strategies at both the public and private level, the critical role of “know who” in integrating with international knowledge networks, and the need to strenghten “absorptive capacity” to fully leverage external expertise.

However, as Abramovitz’ (1986) hypothesis emphasizes the indispensability of “social capability” for successful catch-up, this thesis makes a more distinct departure from incumbent TIS approaches to posit that **legitimization and counteracting resistance to change (F7)** should also encompass ensuring the legitimacy of the political process and building institutional adaptive capacities at the national level. This is particularly critical in transition contexts, where underdeveloped networks and resistance to change can hinder efforts to foster an environment supportive of technological advancement. Applying this framework bridges the TIS and NIS approaches while emphasizing their interconnectedness.

The ensuing section addresses the second research question, applying the adapted framework to the case of the emerging AI TIS in Armenia to evaluate its development and challenges in functional terms. This analysis aims to inform a broader review of NIS dynamics and technological catch-up capacity, provide potential justification for refining the framework, and identify areas for future research to explore the findings' implications and limitations.

2. RESEARCH METHODS

This study employs a qualitative, mixed-methods research design to investigate the dynamics of emerging AI TIS development within Armenia's transition NIS. Given the limited scope of this thesis, the research focuses on key developments since 2016. While some private sector actors engaged in AI development prior to this period, 2016 marked the inception of deliberate system-building efforts, driven by the emergence of three key network organizers. The shift was catalyzed by the convergence of the growing global prominence of AI, the local system's capacity to engage with the sector, and the perceived urgency to prioritize strategic technological advancement following a significant national geopolitical shock (Interviews 2, 3, 5, 7, 8).

After tracing system development through the adapted framework (Figure 2), the thesis will review network organizers' efforts to catalyze "motor B" through two parallel 2023 advocacy efforts: securing public investment for graphics processing unit (GPU) infrastructure and developing a public AI education program. Each initiative showcases the dynamics of **legitimization and counteracting resistance to change (F7)** and the importance of accounting for political legitimacy and building institutional adaptive capacity in the Armenian context. Ultimately, these results facilitate a discussion about the "structural causes of functional weaknesses" (Jacobsson and Bergek, 2011, p. 46) at the national level and the development of "social capabilities" relevant to technological catch-up.

2.1. DATA COLLECTION AND ANALYSIS

The first phase of data collection establishes the historical context and structure of Armenia's NIS and emerging AI TIS (Appendix 5). Desk research included a literature review and document analysis, with reports from organizations like the United Nations (UN) and World

Bank highlighting legal reforms and innovation challenges. Supplementary data from government documents, press releases, academic publications, social media, news outlets, and industry reports provided insights into partnerships, funding, and project outcomes.

The second phase involved conducting in-depth, open-ended interviews with eight key stakeholders in the AI system. A snowball sampling method (Patton, 2023, p. 75) was employed to identify information-rich interviewees, including representatives of three primary network organizers: YerevaNN, Smartgate VC, and the Foundation for Armenian Science and Technology (FAST). Supplementing the "reported" events (Hekkert et al., 2007, p. 427) with context from interviews proved crucial, as understanding the ongoing dynamics of network alignment in Armenia's AI TIS requires deeper insights that are not captured in secondary sources.

FIGURE 4. INTERVIEWS

	Title	Organization	Type	Date
1	Co-founder/CEO	Krisp	Firm	7/1/23
2	Managing Director	Gituzh	Advocacy coalition	27/10/23
3	Co-founder/partner	Smartgate VC	Venture fund	30/10/23
4	Researcher	YerevaNN	Research lab	30/10/23
5	Director	YerevaNN	Research lab	31/10/23
6	Program manager	MoHTI UNDP SDG Lab MoE	Public sector International organization Public sector	1/11/23
7	VP Strategic Programming	FAST	Foundation	9/11/23
8	Founder/CEO Professor	Feedbank Intelligence YSU	Startup University	20/11/23

As opposed to relying solely on functional indicators to illustrate system development, the analysis aligns with Bergek's (2019, p. 17) call to "move beyond [them]" and engage in "more in-depth qualitative analysis to establish causal relationships between events and functional processes." Consequently, rather than quantifying or visualizing data, this thesis adopts a narrative approach to present the functional pattern, utilizing Radosevic's (2002) concept of "network organizers" as a tracing mechanism. This narrative pattern does not aim to provide a definitive assessment of system performance, but rather enables an exploration of stakeholder perception of key functional developments and the degree of "virtuosity" of their fulfillment Ultimately, these insights contribute to the research objective of facilitating a broader discussion of the challenges and opportunities of the AI TIS relevant to technological catch-up.

2.2. VALIDITY AND RELIABILITY

This research faces several key limitations that reflect the "inherent uncertainties" of emerging TIS and the challenges in identifying structural components (Bergek et al., 2008, p. 414).

While detailed qualitative data is indispensable for TIS analysis (Bergek, 2019), prioritizing "stories over statistics" (Patton, 2023, p. 78) complicates the reliability of the conclusions. Establishing causality between initiatives poses a challenge, as it is often unclear what outcomes were inevitable over time versus those resulting from targeted efforts.

The research would have further benefited from additional stakeholder interviews, particularly with public sector decision-makers. Although two of the three primary innovation-related public bodies were represented—both the Ministry of High-Tech Industry (MoHTI) and the Ministry of Economy (MoE)—a representative from the Ministry of Education, Science, Culture, and Sports (MoESCS) Science Committee would have provided invaluable insights into the public sector perspective. Additionally, as noted in the introduction, the model was primarily developed for analyzing sustainable technologies, which may limit its applicability to the unique dynamics of AI.

Carlsson et al. (2002, p. 244) question the validity of IS performance evaluations, arguing that analyzing performance "at a particular time is not only problematic, but can also be misleading," since the most significant aspect of performance—contribution to long-term economic growth—can only be assessed retrospectively. Another key debate in NIS theory revolves around whether the concept is insufficiently or excessively theorized (Sharif, 2006, p. 757). This thesis aligns with Guinet's (2003, cited in Sharif, 2006, p. 758) perspective, which posits that the power of NIS as a framework is its ability to "tell a convincing story" about the relationships between seemingly disparate subjects.

Despite these caveats, the research design serves as a reliable mechanism for reviewing IS development and technological catch-up efforts in Armenia. It demonstrates the utility of IS as a "heuristic" device for exploring complex phenomena rather than as a rigid diagnostic tool (Hekkert et al., 2007, p. 414), and responds to the need for adapting the functions of TIS model to diverse contexts. While the results should be viewed as a guide to further research rather than definitive, they enable a discussion of the second research question: exploring the functional developments and challenges of the emerging AI TIS and their implications for understanding broader NIS dynamics related to technological catch-up.

3. RESULTS

This section reviews the development of Armenia's post-Soviet IS, identifying historical path dependencies and "favourable conditions" (Perez and Soete, 1988, p. 476) that underpin the nation's potential for high-tech innovation. By applying the adapted framework to the emerging AI TIS, this analysis demonstrates how the functional approach may offer a more effective alternative to the structure-based NIS model, particularly in identifying ways to foster the "social capabilities" necessary to mitigate fragmentation and drive the technological and institutional changes required for Armenia's catch-up.

3.1. ARMENIAN NIS

While Armenia played a pivotal role as a center for high-tech military industrial development in the USSR, its research infrastructure failed to adapt to the transition to a market economy (Khnkoyan, 2012, p. 78). As the first decade post-independence was marked by a devastating earthquake, war, and an energy crisis, policies were focused on short-term disaster mitigation rather than development (Poghosyan, 2017, p. 57). Only after 2000 did policies shift towards a long-term, innovation-oriented approach, with the first "Law on Scientific and Technological Activity" outlining principles for state science and technology policy (Ibid., p. 59). The first

“Law on Innovative Activity” was passed in 2006, with successive legislative efforts aimed at fortifying a national science and technology ecosystem (Appendix 1).

As Armenia's economy steadily improved, the World Bank's 2007 *Caucasian Tiger* report optimistically characterized its high growth rates as "a case study of success in post-Soviet economic transition" whose catch-up efforts were “reminiscent of the east Asian tiger economies” (Mitra et al., 2007, p. xvii). The report credited success to robust structural reforms, including privatization and trade liberalization, which helped integrate Armenia into the global market economy (Ibid., p. xx). However, it also advocated for targeted efforts towards strengthening the IS—particularly through enhancing knowledge networks and linkages among actors (Ibid., p. xxx).

Alongside improvements in the general economy and macroeconomic environment (Appendix 2) in the years following the report, successive administrations would identify development of Armenia’s NIS “among the government’s priorities” *(“Armenian PM,”* 2014). However, this character of public support was largely “declarative,” lacking both the necessary financial commitments and metrics for measuring success (Danielyan, 2009, p. 40). Initiatives, though ostensibly aimed at establishing a supportive regulatory foundation for a NIS, lacked enforcement mechanisms, clear timelines, and a long-term vision to ensure their effectiveness (Ibid.). Emblematic of the lack of high-level commitment to science and technological development, one of the most critical benchmarks for innovation—public expenditure on R&D—fell short of established standards (Appendix 3). The most recent Global Innovation Index (GII) ranked Armenia 63rd of 133 countries, according to an assessment of additional benchmarks including education and research expenditure, graduates in sciences and engineering, venture capital (VC) funding received, as well as other relevant metrics (Appendix 4).

One of the issues in effective system development, Poghosyan (2017) posits, was confusion in utilizing the NIS model as a policy justification. Reforms were “narrow,” focusing on structural interventions rather than fostering the essential interactions among system actors needed to mitigate fragmentation (Ibid., p. 59). An overreliance on international donor funding led to investments in new organizations, such as the World Bank-funded Enterprise Incubator Foundation (EIF), that prioritized measurable outcomes to satisfy donors but lacked functional impact (Ibid., p. 60). The situation was further complicated by an absence of a unified vision for innovation within the country, with the MoE and MoSECS—the two primary bodies overseeing innovation and science—divided in their approach, the former emphasizing market-driven initiatives and the latter focusing on science-oriented strategies without any coordination of their efforts (Ibid., pp. 59-60).

In February 2019, the post-Revolution government led several institutional reforms to establish centers of excellence in science and technology (Interview 6). The Ministry of High-Tech Industry (MoHTI) was established to support this endeavor, as well as reinstate the previously-dormant National Center for Innovation and Entrepreneurship (NCIE) under the MoE (Ibid.). Another organization established with World Bank funding, "Engineering City," was created to host an ecosystem of high-tech companies (Enterprise Incubator Foundation, 2019). Although industry actors welcomed MoHTI initiatives such as updates to the tax code and new grant programs, the focus on structural changes could be more accurately characterized as "rebranding" efforts than truly transformative actions for the IS (Interview 6).

The recent 2023 UNECE Report on Armenia's IS indicated that, despite two decades of efforts to reform and achieve high-tech ambitions, systemic weaknesses persist (UNECE, 2023, p. 59). Following the release of the report, which highlighted many of the same challenges outlined nearly a decade prior (UNECE, 2014) the then-Minister of HTI stated that "only through coordinated national innovation policy can we avoid overlaps, build up synergies and accelerate the innovation-based sustainable development of Armenia" ("*Robert Kocharyan,*" 2023). Frustration was growing among members of the science and technology community, who—while agreeing with the report's conclusions—questioned why "millions of dollars are being spent on saying what we already know" (Interview 7). Such efforts reflected that while the Revolution promised legitimate change, rhetoric was never fully actualized. The focus of innovation policy remained on new infrastructure rather than addressing fragmentation, going against Radosevic's (2002, p. 87) assertion that "emphasis should be on functions and programs rather than on new organizations." Most recently, legislation proposing the creation of an "Academic City"—a plan to relocate existing public universities on a new, collective campus—has drawn criticism from advocacy networks (*"Gituzh,"* 2023). They argue that the project's vision and allocation of funds exemplify a broader pattern of misguided IS policy (Interviews 2, 7).

Despite the challenges in building Armenia's NIS, the country reflects the ambivalent legacy of its Soviet past, exhibiting some promising preconditions for high-tech innovation (Poghosyan, 2017, p. 50). Its historical role as an R&D center within the centralized research system has endowed Armenia with a "strong global comparative advantage in mathematics and natural sciences" (Onugha, 2020), and although the severe brain drain of the 1990s depleted much of the country's human capital, it also fostered a robust diaspora network where many Armenians acquired advanced training abroad (Poghosyan, 2017, pp. 49-50). The diaspora provided the necessary "cultural proximity" needed to establish international linkages, facilitate knowledge transfer, and enhance technological capabilities and the business acumen vital for competing globally (Kitanovic, 2007, p. 38).

An assessment by FAST highlighted that by 2017, what remained of Armenia's Soviet-era science ecosystem had "almost vanished," with the remaining scientists and engineers rapidly aging out of the workforce (Interview 7). However, as noted by Pavitt (1997, p. 54), brain drain can be a "boon" if countries create conditions that promote repatriation. Diaspora Armenians forged new ties to the homeland, establishing firms that laid the groundwork for a nascent technology cluster within Armenia's fragmented NIS and cultivating a strong, global community and collective "entrepreneurial spirit" (Carlsson and Jacobsson, 1997, p. 303) (Interviews 1, 3, 8). The influx of foreign investment and expertise originally spurred the emergence of Armenia's "first generation of startups" (UNECE, 2023, p. 67), positioning Armenia as a "technological nation" (UNECE, 2023, p. 75). However, this characterization is somewhat misleading; while Armenia has excelled at importing knowledge from abroad, it has struggled to generate it locally (Interview 7). Discussions about Armenia's advancements in science and technology should recognize that developments stem primarily from the diaspora, rather than a functional NIS (Interviews 3, 7).

A positive trend in Armenia's innovation ecosystem is the growing number of Armenian scientists and entrepreneurs leveraging diaspora connections to launch businesses in global hubs like Silicon Valley (Interviews 1, 3, 8). These ventures allow them to gain mentorship, funding, and sales expertise before returning to Armenia to establish engineering bases, helping overcome local infrastructure challenges (Interviews 1, 8). In addition to securing funding abroad, there is a small but growing base of Armenia-based VC firms and other investment channels (Appendix 6). In 2021, local startups collectively generated more than $200 million in funding (Satourian, 2022a), many of which have gone on to excel in global markets (Appendix 7).

Despite notable progress, the rapid pace of technological advancement, combined with the mounting challenges facing the nation, highlights a critical tension between sector-level actors' technological capacity and lack of adequate national "social capabilities" needed to accelerate its development. This dichotomy is clearly illustrated by the swiftly evolving AI sector, where the necessity for institutional adaptability needed to effectively engage with the private sector in a productive way is paramount for capitalizing on the current "window of opportunity" in the global system. The emergence of several key network organizers and their collective activity signals that fragmentation is being addressed, though the public sector resistance to change in developing sector-supportive initiatives remains substantial. The following section will provide an outline of the emerging TIS using the adapted functional framework before examining lobbying efforts that drive **legitimization and counteracting resistance to change (F7)** within Armenia's AI ecosystem. It will then assess the "virtuosity" of these initiatives and their implications for the dynamics of Armenia's NIS in relation to technological catch-up.

3.2. EMERGING AI TIS

Although Armenia's involvement in the global AI industry has been a focal point of national discourse on technological development (Israyelyan, 2023), there has yet to be a systematic analysis of its progression. This section addresses this gap by applying the adapted functional framework to examine the emergence and evolution of the national AI TIS. It evaluates the degree of network alignment and system functionality, with a particular focus on **legitimization and counteracting resistance to change (F7)**. The analysis highlights the interplay between TIS dynamics and broader challenges within Armenia's transitioning NIS, supporting Abramovitz'

(1986) hypothesis that social and institutional factors are as critical as technological capacity in facilitating national catch-up.

Following the functional interpretation of Perez and Soete's (1988) three stages of emerging TIS development (Figure 2), this section draws on stakeholder interviews to chart the evolution of the Armenian AI system, which gained momentum in 2016 with the activity of three key network organizers.

The first stage of an emerging TIS is actors' capacity to recognize new opportunities and favorable conditions, represented functionally through entrepreneurial activities (F1) and guidance of the search (F4).

The development of the Armenian AI knowledge network can be first traced to 2016 with the establishment of **YerevaNN**, a non-profit research lab founded by postgraduate students of Yerevan State University's (YSU) Faculty of Informatics and Applied Mathematics (Interviews 4, 5). Initially, there was uncertainty about the organization's structure—whether to be a research arm of a company or a consulting service. Ultimately, YerevaNN chose the "experimental" and somewhat "radical" non-profit path, focusing solely on publishing research without immediate intentions to impact the economy or society (Interview 5). Their strategy is to build capacity in the AI field in niches with strong growth potential, with the intention that they could eventually spin-off into commercial applications (Ibid.).

Although those working on AI had advanced backgrounds in math and sciences, they were primarily self-taught as no graduate courses were available in deep learning and ML at local universities (Ibid.). The director of YerevaNN emphasized that the first instance of formalized training in AI should be attributed to Armenian Code Academy (ACA), a Yerevan-based organization that had approached a diasporan Armenian from the Massachusetts Institute of Technology (MIT) to design and implement a six-month course in 2016 (Ibid.). This initiative is recognized as transformative, as graduates later went on to lead ML teams across various companies (Ibid.). YerevaNN's early participation in the emerging AI system mirrors the trajectory outlined by Perez and Soete (1988): team members initially learned from freely available materials which paved the way for the institute to publish its own well-received guide to machine learning (ML) in 2017. This, alongside paper submissions to international AI conferences, solidified YerevaNN's legitimacy as a research institution as well as helped put Armenia on the map as a valuable contributor to the AI knowledge base (Appendix 8). The research institute's Board of Directors includes several key members of the local AI community, and early funding from extant AI companies—whose success increased the visibility of AI as a promising national sector (Appendix 7).

Another critical development in the local AI TIS was the founding of the **Foundation for Armenian Science and Technology (FAST)** in 2017, a diaspora-led initiative established to promote research and innovation in high-impact science and technology fields. Recognizing the growing potential of AI in Armenia, one of FAST's first initiatives was to organize a ML conference in partnership with the US National Science Foundation (NSF) (Interview 7). The event was the first formal event bringing local and global actors in the ecosystem together to discuss Armenia's potential role in the international AI field, "ahead of the global hype" (Ibid.). FAST would go on to collaborate with the World Bank, influencing the direction of the international organization's 2020 report *Realizing Armenia's High-Tech Potential.* The publication marked a turning point by drawing significant attention to Armenia's high-tech sectors, highlighting several fields where—with an appropriate regulatory framework and investment—Armenia could excel (Onugha, 2020). Drawing on the nation's "strong legacy in math and science," it echoed YerevaNN's resolve that Armenia has the potential to become a "global hub for pure AI research" (Ibid., VII).

These developments helped substantiate a narrative positioning Armenia as a potential nexus for global AI development, as well as signaling to the government that the sector should receive public support—a vision that would find champions in Armenia's post-revolution administration (Interviews 5, 6, 7). Although the nascent MoHTI had no specific legislation targeting AI development, it assumed an "unofficial" AI mandate, with various other government bodies adopting favorable posture towards AI after the release of the World Bank report (Interview 7). In 2021, Deputy Prime Minister (PM) Tigran Avinyan published an article outlining ideas regarding an "Artificial Intelligence Strategy for Armenia," arguing that the country is "fairly well poised to become a hub for basic research with little capital commitment" (*"Tigran Avinyan,"* 2021). He advocated that solidifying a strategy should be a "top priority for Armenia today" (Ibid.). In a 2022 conference on "Prospects of Artificial Intelligence in Armenia," former Minister of HTI Vahagn Khachaturyan framed AI as critical to building Armenia's high-tech capacities, warning that not participating would mean "lagging behind" (*"High-tech minister,"* 2022).

However, despite ostensible support for the sector, little has been done on the government's end to promote system development aside from funding limited grant opportunities (Appendix 6). These contributions were driven entirely through appeals from the private sector rather than internal impetus (Interview 6), with the overall structure of the TIS reflecting this divide (Appendix 5). This trend raised concerns among AI proponents, who contended that the government should take a more active leadership role in system development, citing the strategic importance of AI technology not only for the broader economy but also for military modernization efforts (Interviews 2, 3). AI-centered companies have attracted considerable investment (Appendix 7), two of which—Service Titan and Picsart—have reached unicorn status in 2018 and 2021, respectively. These "success stories" have served to inspire other startups and entrepreneurs, as well as signal opportunity for growth in the sector (Interview 1).

Both YerevaNN and FAST recognized the 2016 Four Day War as a catalyst for coordinated system-building efforts (Interviews 5, 7). This reflects how "disruptive" crises can galvanize collective action, promoting network cooperation (Radosevic, 2002, p. 90) and strategic investment in such clusters with significant growth potential (Perez and Soete, 1988, p. 476). Both network organizers capture the importance of connecting diaspora-local networks, which in the absence of public support would rely heavily on resource mobilization from foreign funding streams to empower local system-building efforts (Interviews 5, 7).

Having articulated the "window of opportunity" for participating in the emerging global AI TIS, the network must exert the competence and imagination to design an effective strategy to participate in it, mobilizing resources (F6) towards knowledge development (F2) and diffusion through networks (F3).

With YerevaNN and FAST both securing donations from diaspora partners, an indispensable development in the AI TIS was the entry of **SmartGate VC**, a California and Armenia-based pre-seed deep tech VC fund. Not only investing in early-stage ventures, SmartGate played the critical role of developing marketing and sales capacity in local firms (Jacobsson and Johnson 2000) (Interview 3). Aided by an EU grant, the firm established Hero House under its community arm Catalyst Foundation to provide entrepreneurs with the resources and opportunities to bring their ventures to market and scale (Ibid.). The firm's co-founder and partner strongly emphasizes that the national funding landscape in Armenia is inadequately represented as, should a diaspora investor decide to inject capital, "the next morning everything in Armenia would change" (Ibid.). This comment highlights the critical role of diaspora investment in transforming Armenia's innovation ecosystem, where external funding could catalyze significant shifts in the national technology landscape.

While much of early efforts focused on startup incubation and acceleration programs, both SmartGate VC and FAST noted a deliberate shift in strategy towards deep tech venture-building, recognizing that products built on top of existing software stacks offered a significantly weaker value proposition compared to developing native technologies (Interviews 3, 7). However, the prioritization of deep tech highlighted several shortcomings of the local education system: while universities were beginning to introduce AI-related masters programs, there remained a gap of postdoctoral training opportunities (Onugha, 2020, p. 14) (Interviews 1, 5, 8). YerevaNN tried to help mitigate this problem through developing the Gitak platform, which aimed to connect local students with supervisors abroad (Mkrtumyan, 2021). Although the program successfully matched over a dozen projects, YerevaNN's director emphasizes that while remote collaboration can be helpful, local partnerships are far more valuable for advancing AI research (Interview 5). To facilitate this, FAST launched the ADVANCE research grant connecting local research initiatives with international Principal Investigators (PIs), funding their travel to Armenia to oversee three to four-year projects in relevant scientific fields such as AI (*"ADVANCE,"* 2022). This model inspired a similar program under the MoESCS, which launched both the Launch Armenia Research Fellowship (LARIK) and Consolidate Armenia Research Fellowship (CARIN) to fund foreign scientists Armenia-based projects over a five year period (*"Science Committee,"* 2022).

Aside from the primary network organizers, several other pivotal actors in the system launched initiatives to support knowledge development in the AI TIS. Of these, one of Smartgate VC's most influential portfolio companies, Krisp, had introduced several transformative initiatives aimed at facilitating AI research, including partnering with YSU to develop an AI Lab (*"YSU-Krisp,"* 2022), as well as open a VC firm to "help exceptional Armenian founders build high-impact, global companies" (Satourian, 2022b). Krisp's co-founder and CEO is vocal that "there is a technology boom in Armenia," and that those not involved are "missing out" (Interview 1). In addition to long-established R&D centers working in AI, such as VMWare, Synopsys, and Siemens (Appendix 5), a major milestone in the Armenian AI TIS was the diaspora-driven establishment of an NVIDIA R&D center, representing one of the most influential AI companies globally (Appendix 11).

FAST, SmartGate, and YerevaNN have all dedicated substantial resources to organizing annual conferences in support of the AI industry, focusing on global visibility, ecosystem convergence, and academic research, respectively (Interviews 3, 5, 7). FAST's Global Innovation Forum (GIF) focuses on generating broader visibility, leveraging their network to feature prominent AI industry leaders, helping to bolster Armenia's credibility within the international AI ecosystem (Interview 7). SmartGate VC's Science and Technology Convergence Conference (STCC) focuses more on facilitating dialogue between local stakeholders and establishing partnerships across different stages of the development pipeline (Interview 3). YerevaNN established the DataFest conference as a means to promote collaboration and visibility for Armenian AI research, facilitating knowledge exchange among local and international experts (Interview 5). The event helps build individual relationships indispensable to gaining access to critical insights into changing industry trends and relevant research fields—the most significant of which are increasingly "paywalled" and "gatekept" (Interview 4). Each of these initiatives is testament to the outsized value of "know-who" in the technology system, overcoming Armenia's relative geographical isolation with connections to the global AI TIS indispensable to keeping up with developments and industry trends.

Despite these developments in the local AI TIS, there is growing concern among interviewees that Armenia could miss out on the next wave of AI development, as recent innovations in areas such as generative AI have rendered many research fields obsolete (Interviews 3, 4, 5). As the landscape has shifted from open collaboration toward increasing privatization, network organizers have underscored the need for a proactive approach to identifying and participating in niches where there still is potential for comparative advantage (Ibid.). These include applications in chemistry and drug discovery, shifting away from large language models (LLMs) and computer vision where the market share is increasingly consolidated by AI giants such as Google and Meta (Interview 5). YerevaNN has taken a leadership role in coordinating the local biotech ecosystem, hosting weekly reading groups to present papers and share knowledge in the rapidly-developing field (Interview 4).

In order to effectively implement these strategies, there has to be adequate institutional conditions and political will to carry it through, a product of the creation of legitimacy and counteracting resistance to change (F7).

The defeat in the Second Nagorno-Karabakh war in 2020 called for renewed commitments to strengthening Armenia's science and technology system as a means of safeguarding national sovereignty (Interviews 2, 3, 8). This urgency has spurred the emergence of advocacy coalitions such as **The Gituzh Initiative** and the **Armenian Society of Fellows (ASOF)**, which, alongside fellow network organizers, have intensified efforts to lobby the government for stronger reforms and investment towards enhancing the country's innovation system—emphasizing how innovation is "at its core a political issue as much as a technological one" (Interview 2).

Gituzh is a network of professionals from Armenia and the diaspora established in 2021 with the mission to revitalize the country's scientific ecosystem; "empowering Armenia through science and technology," and emphasizing the critical role of public R&D funding for national development and security (*"The Gituzh Initiative,"* 2021). Supported by nearly 200 leaders in the Armenian science and technology community, Gituzh's first action was to present three key demands to the government: increase funding for scientific activities, introduce legislation to gradually boost R&D investment, and establish a state body to manage strategy (Interview 2). While the government's response has fallen short of these aims, pressure from the advocacy network did succeed in raising the budget for scientific funding, as well as imbue a larger sense of accountability on the public sector to revitalize Armenia's legacy of scientific excellence (Interview 2).

ASOF is a global network of leading scholars and professionals from Armenia and the diaspora, dedicated to advancing Armenia's development (*"About ASOF,"* 2021). Their initiatives are divided into two types, smaller-scale exploratory programs and transformative large-scale projects designed to spin off as independent entities (Ibid.). The organization's mission is to elevate the nation's education and research institutions to "world-class" levels and foster an internationally connected civil society capable of positioning Armenia as a contributor to addressing both local and global challenges (Ibid.). Alongside other high-value domains, ASOF leads an AI & Deep Learning Task Force aimed at articulating a strategy for the development of an Armenian AI knowledge network (Interviews 2, 3, 5).

Though each initiative's objective is larger than AI alone, both advocacy groups have developed close ties with leaders in the AI sector, as their incentives are directly aligned in building a more robust Armenian science and technological system (Interviews 2, 3, 5). In 2023, collective efforts conceptualized a National AI Institute, aimed at capturing the closing "window of opportunity" in the international AI landscape (Ibid.). Both advocacy networks, SmartGate, and YerevaNN formed a coalition—aided by influential AI leaders from the diaspora—to lobby the government for investment in a GPU supercomputer in the 2024 national budget (Ibid). They viewed this hardware as critical to exponentially improving local researchers' output and facilitating integration into the global AI research ecosystem (Ibid.). While FAST supported public investment in research, they notably diverged in their strategy—choosing to engage the government in broader educational capacity-building initiatives rather than focusing on hardware investments (Interview 7).

This process, in which entrepreneurs **(F1)** actively lobby **(F4, F7)** for favorable economic conditions **(F6)** to drive technological progress **(F2, F3),** provides a helpful lens for assessing the "functionality" of Armenia's AI TIS-building efforts. The initiatives to fund a supercomputer and launch an educational program pilot highlight institutional capacity limitations rooted at the national level. By tracing the "motor B" functional pattern (Figure 3), the following case enables a deeper examination of two key aspects of **F7**—political legitimacy and the development of institutional adaptability—informing a broader discussion on dynamics within the NIS and the degree to which efforts should be considered "virtuous."

3.2.1. Functional Pattern

The lobbying efforts for public investment in GPUs—lead by YerevaNN, SmartGate VC, ASOF, and Gituzh—was galvanized primarily by two exogenous shocks to the global AI TIS in spring 2023, which actors argued posed serious threats to Armenia's role in the system (Interviews 3, 4, 5). The first was the release of GPT-3 by OpenAI, which rendered various local ventures and research initiatives in LLMs obsolete (Ibid.). The second involved the U.S. export restrictions on NVIDIA's advanced AI chips, barring sales to China and potentially similar competing markets (Cherney and Nellis, 2023) (Interviews 4, 5). This raised concerns that Armenia might face similar restrictions, intensifying calls for the government to commit to acquiring the hardware indispensable to AI development while it remained accessible (Ibid.).

Each development prompted proponents to advocate for infrastructure investments necessary to enable Armenia's competitive contribution to still-relevant research fields, as one of the biggest challenges facing AI research institutes like YerevaNN was that technological capabilities far exceeded existing infrastructure capacity (Interviews 4, 5). Access to computing resources needed for training large models is a critical factor, as according to a researcher at YerevaNN, the "speed of interation" in R&D does not scale linearly but "exponentially" (Interview 4). With the proposed GPU investment, a model that would take 460 days to train could be reduced to under 20 minutes (Ibid.). He emphasized that this not only would enable handling larger datasets and more ambitious projects, but offer greater flexibility and the ability to pivot quickly: essential factors for experimental design and cultivating "scientific intuition" necessary for innovation in the AI field (Ibid.).

The GPU lobby's public advocacy began with an article outlining a vision for an "AI Institute for Armenia," highlighting the transformative potential of advanced computing for the nation's economic, technological, and security (Israyelyan, 2023). The piece emphasized Armenia's potential as a hub for AI development, stressing the need for AI R&D infrastructure and the attraction of human capital to drive it (Ibid.). Central to this vision was a proposed supercomputing center, led by YerevaNN and located at YSU, aimed at supporting industries from defense to healthcare, and calling on the government to prioritize AI development (Ibid.).

As one of the core owners of the proposal, YerevaNN engaged the public and government officials at forums like the Digitec conference, presenting data that substantiated the need for the investment (Appendix 9). This led to dialogue with the MoHTI, which would serve as the main body coordinating with industry representatives (Interview 5). Diaspora-enabled collaborations with institutions such as Meta and the University of Southern California (USC) gave persuasive weight to these discussions, underscoring Armenia's need for increased computational capacity in order to keep pace with the fast-developing global AI system (Interview 4). An influential partner from Meta and key driver of the advocacy initiative stated in an interview that "one of my interns has more GPUs than all of Armenia. I think this is a strategic mistake" (Grigoryan, 2023b). Similarly, a diasporan NVIDIA executive leading the Yerevan-based R&D center reiterated that the local ecosystem was "ready" for serious infrastructure investments (Grigoryan, 2023a).

Parallel to these efforts, FAST had also approached the government to increase its commitment to establishing the necessary foundations for AI development in Armenia—a reflection of their mandate to build the national science and technology ecosystem (Interview 7). Rather than infrastructure investments, they targeted early education as the best avenue for long-term system development, aiming to "create an educational and career pipeline of AI researchers and innovators" (Ibid.). The foundation drew on its community of international experts to design the strategy and curriculum for the "Generation AI" program, which would introduce math-intensive foundational skills for AI research and development at the high school level (*"Generation AI,"* 2023) (Appendix 10).

After successfully pitching the program to partners at the MoESCS, a public-private partnership was formed to jointly implement the program (Interview 7). The initiative fell under the scope of the Ministry, and therefore did not require the same degree of outward advocacy as the GPU lobby (Ibid.). Nevertheless, its organizers emphasize that the process was designed to establish the necessary routines and internal capacity for iterating and improving the initiative, ensuring its sustainability once ownership was fully transferred to the government (Ibid.). FAST asserted that the process was designed not to develop Generation AI in isolation, but instead to "serve as a model for public-private partnerships" with the government moving forward (Ibid.).

Ultimately, while both advocacy initiatives were successful in mobilizing resources towards greater knowledge development—the government committed $8.5 million to GPU capacity (Appendix 12), and launched Generation AI program across 16 high schools in six regions across Armenia (Interview 7)—the extent to which this fulfillment of **F7** should be considered "virtuous" warrants further examination. While the long-term impact of the functional pattern remains uncertain, it provides insights into the roles of network alignment, political legitimacy, and institutional adaptability, all of which are critical "social capabilities" underlying a nation's capacity to promote technological catch up.

3.2.2. Assessing Functionality

The functional pattern of advocating for the GPU investment and Generation AI program help illuminate network alignment, political legitimacy, and institutional adaptive capacity, which are essential for evaluating the "virtuosity" of the functional cycle. This section will review each of these dimensions and then turn to a discussion of how they inform broader patterns in the NIS.

Alignment

The degree of alignment among system actors—which functions to perform alone, which functions to perform collaboratively, and which functions to compete for (Van de Ven, 1993 cited in Hekkert et al., 2007, p. 422)—was largely shaped by the extent to which they shared a common vision for AI development in Armenia. The research revealed that misalignment did not stem from conflicting views on the importance of AI as a "shortcut to national prosperity" (Interview 3), but rather from differing approaches to where to strategically allocate public resources to achieve it. While there was consensus on the importance of each aspect of the innovation pipeline, inconsistencies emerged regarding how to best advance these goals—whether to prioritize local capacity building through investment in education or to focus on "absorbing" knowledge from abroad—highlights a divergence in conceptions about catch-up strategy. While both approaches are necessary—education as a public good lays the foundation for long-term capacity building, and attracting external expertise provides the speed required to capitalize on the rapidly closing "window of opportunity" for technological catch-up—a lack of consensus on how to integrate these strategies undermined the clarity of resource allocation rationale (Interview 6). Interviewees expressed that alignment is underway, driven largely by the effort to bring stakeholders "into the same room" for more frequent and transparent discussions coordinating "who does what and when" within the system (Interview 7).

Differing ideas on the role the government should play in the system, however, also represent a central point of divergence leading to negative function fulfilment. While collectively acknowledging the capacity limitations faced by the public sector (Interviews 2, 3, 4, 5, 6, 7), there was a split on whether the government should take a more active role in coordinating the system (FAST, YerevaNN, Gituzh) or focus primarily on creating an enabling environment for private sector ownership (SmartGate VC, ASOF). This division has significant implications for the political legitimacy and policy making.

Legitimacy

Rather than solely regarding the technology itself, the concept of legitimacy of an emerging TIS should encompass the policies and political processes behind its development, as they are two key facets to determining the sustainability of initiatives. In the absence of a cohesive national vision and strategy for AI development, there was confusion over the grounds for legitimizing public investment in the sector's infrastructure. While the GPU lobby saw the justification of national investment in AI evident by the industry's potential for global value creation, FAST called for a clearer articulation of "economic benefits to the population" (Radosevic, 1999, p. 278): why, empirically, would computing infrastructure serve national interests "more than roads" (Interview 7)? Ultimately, with this clarity lacking, much of the justification for the investment rested on the PM's meeting with the CEO of NVIDIA earlier that year (Interviews 4, 5) (Appendix 11). This raises questions about the role of appeals to authority in rationalizing sector-supportive policies, as this extrinsic source of legitimization might potentially compromise their "survival and effectiveness" (Carlsson and Stankiewicz, 1991, p. 109).

In addition to the policies themselves, there are also questions of legitimacy around the politics behind their development—navigating conflicts between asymmetric "incentive" (Pavitt, 1997, p. 45) and "power" structures (Dyker and Perrin, 1997, p. 10) between stakeholders. Given the urgency of securing hardware amidst potential import restrictions and rapid developments in the field, the GPU advocacy efforts appeared to prioritize speed over standard procedure. As no existing "institutional mechanisms" (Kitanovic, 2007, p. 29) existed to appeal for their case (Interviews 3), conversations with the government took on an ad-hoc and assertive character, where industry representatives from Meta and NVIDIA were called on to give credence to the severity of the risk should Armenia wait to secure GPUs (Interviews 4, 5). Amidst this, unclear ministerial mandates led to overlapping initiatives and lack of coordination (Interviews 6, 7), with efforts to develop the AI Institute falling under the market-oriented MoHTI rather than the more suitable science-based MoESCS. FAST was critical of the exclusion of the MoESCS in negotiations, wary of the downstream effects should the initiative be conceptualized as more industry-facing, rather than prioritize basic research as its advocates intended (Interview 7). Overall, while system actors were adamant about working towards the same goals, in the absence of institutional capacity the GPU lobby improvised their own "rules" of the game (North, 1990 cited in Kitanovic, 2007, p. 31), while FAST opted to try and co-author new ones through developing a new model of public-private partnership. While the former could be seen as legitimate due to the absence of institutional capacity, FAST's consideration of the "struggles over the right course of action and who gets what and when" is a fundamental aspect of mitigating the challenges of transition fragmentation (Grin, 2010 cited in Markard et al., 2015, p. 81).

Adaptability

As lobbying efforts played a crucial role in **counteracting resistance to change (F7)**, each advocacy group stressed the barriers stemming from "organizational inertia" (Perez, 2010, pp. 198-199) typical of transition institutions. While momentum was built under previous administrations, FAST attributed the "complete lack of institutional memory" (Interview 7)—the inability to "[unlearn, learn or relearn]" (Perez, 2010, p. 199) new routines through regime changes—as a significant obstacle to sustaining long-term initiatives. Whenever leadership changed, relationships had to "start from scratch," as the absence of intentional learning and "forgetting" processes led to a constant reset, undermining the progress made under previous leadership (Ibid.). While FAST aimed to break this cycle of "reinventing the wheel" (Radosevic, 1999, p. 284) through formalized mechanisms for knowledge sharing and relationship-building, the GPU coalition assumed a more immediate and pragmatic approach given the perceived urgency of their aims.

Though costly and "complicating" their work, FAST intentionally implements initiatives in partnership with ministries—structuring programs, "de-risking" pilots, and then spinning off to government ownership if they prove to be successful (Interview 7). While this strategy promises to help build institutional competencies, whether they will be sustained in the long-term is a product of instilling the capacity to continuously learn and "creatively" forget old routines unsuitable for meeting evolving demands of technological transformation (Kitanovic, 2007, p. 32). FAST suggested that while the GPU lobby's focus on building high-tech capacity is essential, it must not overshadow the equally complex task of developing the institutional foundations required for a functioning IS (Interview 7). Otherwise, potential gains may be lost to the path of "low-end forgetting" (Kitanovic, 2007, p. 41). This pattern reinforces the tension arising from "advanced" technological clusters operating within a "backward" IS, and the imperative to focus both on building the "social capability for technical and institutional change" at the national level (Freeman, 2002, p. 203).

While institutional barriers are frequently brought up informally, interviewees noted that they are not often the focus of formal dialogue (Interviews 1, 2, 3, 5, 6, 7). However, the successful campaign for AI infrastructure investments suggests that this might be changing—as it led to a much broader development, the establishment of a Science and Technology Development Council under the PM's office (Appendix 13). The council, whose members include related government ministries and bodies as well as representatives from leading members of the Armenian science and technology ecosystem, potentially signals a more sustained commitment to institutional reform and coordination between public and private stakeholders (*"PM Pashinyan,"* 2024). In the council's inaugural session, the PM asserted that the RA "has many obstacles on its development path, and our perception is that one of the primary tools to overcome these obstacles is science and the technological sector" (Ibid.). However, if the focus is not on addressing the processes underlying innovation, there is a risk that it could follow the path of infrastructure initiatives common to the Armenian approach to IS-building: more token than transformative.

The "virtuosity" of TIS-building patterns reflects the extent to which activities contribute to developing the "social capabilities" necessary to address systemic fragmentation at the national level. The success of each AI advocacy initiative highlights the indispensability of network organizers, whose patterns of affecting change provide insight into the nature of addressing the problems endemic to transition contexts (Jacobsson and Bergek, 2006, p. 703). Ultimately, the success of an emerging TIS hinges on the efforts of these networks to participate in the development of emerging TIS during key "windows of opportunity"—primarily determined by the degree of "alignment" on vision and strategy (Carlsson and Jacobsson, 1997, p. 301). Both Hekkert et al. (2007, p. 426) and Jacobsson and Bergek (2006, p. 703) suggest that research into these patterns of change could provide valuable insights into how momentum is built—or impeded—in developing a new system. While the Science and Technology Development Council will be similarly foundational for coordinating NIS development remains to be seen, it suggests a promising development towards cultivating the institutional capacity indispensable to technological catch-up.

The functional review of the emerging AI TIS in Armenia is not meant to be exhaustive but rather recounts the general "storyline" of development. The findings will help inform the following discussion of the potential developments and challenges within the emerging AI TIS in functional terms, as well as how these insights inform an understanding of broader NIS dynamics relevant to the nation's capacity for technological catch-up.

4. DISCUSSION

This thesis explored IS dynamics in Armenia through applying the functions of TIS framework, adapted to better account for transition context. The following discussion addresses the second research question: assessing the potential developments and challenges of the emerging AI TIS in functional terms, while contributing to a broader understanding of NIS dynamics relevant to Armenia's capacity for technological catch-up.

Transition from NIS to TIS

This research examines IS dynamics in Armenia through a functional lens, advocating for a shift from the predominantly structure-based applications of the NIS model to a process-based approach better suited for transition contexts. The findings support this theoretical approach, as the review of Armenia's NIS development highlights that while many transition economies rely on infrastructure and organizational interventions, policy efforts should instead target the core processes underlying innovation (Dyker and Perrin, 1997; Radosevic, 2002). The bias towards the former reflects a dependence on international donors and benchmarks, along with a general trend of emulating Western policies, whereas the latter demands a higher degree of "social capabilities" than is typically found in developing country contexts like Armenia.

Since the shift towards innovation policy in the early 2000s (Poghosyan, 2017), the results indicate that public support for science and technological development in Armenia has not been accompanied by the systemic reforms necessary to revitalize Soviet-era research infrastructure and meet the growing demands of the diaspora-driven entrepreneurial ecosystem. This disconnect suggests a persistent gap between aspirational infrastructure policies—such as the Academic City initiative—with the substantive actions required to address IS fragmentation. While AI is often identified as a "window of opportunity" to position Armenia within a high-value global system, this vision has traditionally remained underdeveloped, lacking specificity and formalization necessary to coordinate and implement a national strategy.

As emphasized in transition economy literature, technological development is a predominantly "social" enterprise (Dyker and Perrin, 1997, p. 7; Radosevic, 1999, p. 280; Kitanovic, 2007, p. 30). Approaching IS analysis through the TIS lens—particularly through the activity of its most important actors, network organizers—helps recenter social interactions over structural elements (Radosevic, 1999) as a more effective locus for intervention at the NIS level. Abramovitz'(1986) catch-up hypothesis underscores the indispensability of these factors, "social capabilities" such as institutional adaptability, in enabling a nation to catch up. While Armenia's emerging AI TIS demonstrates potential for catalyzing technological advancement, the institutional barriers that hindered effective collaboration and policy development may compromise the extent to which functional developments are realized and sustained long-term.

TIS Functional Analysis

Framing Perez and Soete's (1988) outline of the process of participating in emerging technological systems through the lens of Hekkert et al.'s (2007) framework helped contextualize the ongoing development of Armenia's AI TIS within a clear "storyline," while also identifying functional strengths and challenges in relation to its potential to catalyze national catch-up.

The most prominent takeaway concerns the first stage of TIS development, actors' ability to recognize new opportunities and favorable conditions through **entrepreneurial activities (F1)** and the **guidance of the search (F4)**. The findings show that while Armenia has an active and growing base of startups and entrepreneurial initiatives, risk-taking remains predominantly limited to the private sector. This imbalance underscores a key gap in the system, as the literature emphasizes that the success of national technological development is contingent on the public taking a proactive role in driving experimentation and long-term initiatives (Carlsson and Jacobsson, 1997, p. 301).

Currently, the Armenian government's approach lacks the necessary mechanisms to support the process of "trial and error" required for innovation (Radosevic, 1999, p. 313). Administrative culture is not only risk-resistant, but has "no intrinsic motivation to pursue change" (Interview 6). Compounded by a hawkish culture of oversight and monitoring inherited from the Soviet era, civil servants are not empowered to drive reform, as decision-making authority is concentrated at the highest levels within public institutions (Interview 6). As Metcalfe (1994, p. 933) argues, this is an inhibitor to innovation, as "technology policies may fail as readily as the technology strategies of private firms." Failure is important, as is "how well policymakers learn and adapt in light of" it (Ibid.). With initiatives like the Generation AI being the exception, the results reflect that currently, there is a struggle to "forget" the old, "learn" the new, and then "remember" the institutional practices more conducive to technological change (Kitanovic, 2007, p. 42). Consequently, Armenia remains "stuck in the past" (Interview 7).

To address this problem, the Armenian government must work to "embed private initiative in a framework of public action" (Rodrik, 2004, p. 1 cited in Jacobsson and Bergek, 2006, p. 688). However, this requires both technical expertise and leadership to assume ownership and manage risks effectively, capacity that the government does not currently exhibit (Interviews 2, 3, 5, 6, 7). One proposed strategy by YerevaNN's founder would be to launch a small pilot project loosely modeled after the US Defense Advanced Research Projects Agency (DARPA) (Interview 5). Under the leadership of a dedicated program manager from the science and technological community, the project would articulate a "concrete problem to be solved" (Bergek, 2019, p. 11) relevant to the country and coordinate a team of researchers to address it within a realistic timeframe and budget (Interview 5). This approach could not only promote experimentation but also provide a political buffer against potential failures by designating the project manager as accountable for the initiative's success (Ibid.). As it is critical that such an initiative be long-term and aligned with national priorities, it could serve as an opportunity to utilize new GPU infrastructure to help establish its utility and therefore legitimacy as a public investment. If capable of delivering tangible developments, this strategy could also be scaled across other sectors and set a precedent for more effective public-private collaboration in support of IS development.

The second stage, network competence and imagination to design an effective strategy, considered **resource mobilization (F6)** towards **knowledge development (F2)** and **diffusion (F3)**. The findings reflected the primacy of "know-who" as the most important form of knowledge in a transition NIS (Kitanovic, 2007, pp. 39-40), as it helps overcome geographical barriers to integrate the local system with international knowledge networks indispensable to effective participation in global systems. Interviews suggested that "know-who" is particularly crucial for the AI industry, given the increasingly closed nature of industry knowledge needed to remain competitive in fast-changing research fields (Interviews 4, 5). In Armenia's case, these connections were established by the "cultural proximity" (Kitanovic, 2007, p. 38) and "collective identity" (Saxenian, 1994 cited in Carlsson and Jacobsson, 1997, p. 302) afforded by the global diaspora—and particularly its connections to Silicon Valley (Interviews 1, 3, 8). However, network organizers identified a lack of "absorptive capacity" of local actors as the primary barrier to adequately capturing the value of the knowledge and expertise of this global network (Interviews 3, 5, 7).

While there was a ubiquitous call for committing more public resources to AI as a national priority, interviews indicated that the main challenge in mobilizing investments was not the amount of funding, but the strategy behind its allocation (Interviews 2, 3, 7). While in alignment that both are necessary, actors with an ecosystem-building mandate felt long-term initiatives such as public education and national R&D expenditure should be prioritized (Interviews 2, 7), while those from the entrepreneurial ecosystem were partial to faster-acting strategies like startup grant programs and hardware investments (Interviews 1, 3, 8). These visions must be integrated in order for function fulfilment to be efficient and effective, creating "positive feedback loops" that have the potential to "[build] momentum to create a process of creative destruction within the incumbent system" (Hekkert et al., 2007, p. 426).

Lastly, the formation of advocacy coalitions to establish the institutional conditions and political will necessary to implement these strategies underscored **legitimization and counteracting resistance to change (F7)** as the most critical function in catch-up context, as well as the imperative of expanding its scope to include political legitimacy and promoting institutional adaptability in transition contexts where organizational inertia and risk-aversion are deeply ingrained. Tracing two successful lobbying initiatives helped illustrate this dynamic, whose degree of "functionality" helped illustrate broader patterns in the NIS relevant to technological catch-up capacity.

TIS Functional Pattern and NIS Implications

The assessment of the "functionality" of lobbying efforts captured by the "motor B" pattern of change, defined in this thesis as the degree of network alignment, political legitimacy, and institutional adaptability, underscored the nuance of determining the "virtuosity" of TIS functional fulfillment. Rather than evaluating each approach as inherently positive or negative, it facilitates a critical discussion of how the character of overcoming short-term systemic barriers affects the sustainability of not only the individual AI TIS, but the NIS as a whole.

This thesis defined "virtuosity" as the degree to which efforts to catalyze cycles of change simultaneously break the "vicious circle" of fragmentation at the national level. While more evidence is necessary to substantiate the trends exemplified by the functional pattern, the lobbying efforts suggest the ambivalent nature of developing the "social capabilities" necessary for technological catch-up. Advocated through formal institutional channels, the Generation AI initiative explicitly worked to ingrain adaptive capacity within the MoESCS—and therefore fulfills the expanded understanding of **F7** for transition catch up contexts. The nature of the GPU lobby could be regarded as a reaction to the absence of sufficient communication mechanisms between the public and private sector, which—regardless of the infrastructure being a legitimate need of the AI TIS—could undermine the legitimacy of the national investment. The results further substantiate the theoretical assertion that resources should be directed towards understanding and supporting the needs of these network organizers, as they are the primary drivers in mitigating fragmentation (Radosevic, 2002, p. 93).

While performance can only be truly assessed in hindsight (Carlsson et al., 2002, p. 244), the assessment of system functionality was useful in revealing several national-level barriers affecting the capacity for technological catch-up: the lack of cohesive innovation vision and strategy, institutional mechanisms for facilitating collaboration and dialogue, and a public sector culture heavily resistant to not just risk, but any form of change. The establishment of a formal, high-level coordination body like the nascent Science and Technology Development Council suggests that the first two challenges will be addressed, as they are now officially under the auspices of the PM's office. However, it is imperative that this top-down approach be accompanied by bottom-up administrative reforms in order to address institutional risk-aversion at the ministry-level (Interviews 5, 6).

Theoretical Takeaways

While applying the TIS framework in the context of an underdeveloped NIS offers valuable conclusions, it also exposes the model's limitations. Existing applications do not adequately capture the "[development paradox]" (Perez and Soete, 1988, p. 459)—the difficulties developing the institutional “competence to improve competence” (Metcalfe, 1994, p. 934)—faced by developing nations such as Armenia. As Bergek et al. (2008, p. 410) assert, the functional framework needs to be revised “as and when research on IS dynamics provides new insights.” Since realizing advanced “social capabilities” is essential to the catch-up hypothesis as well as IS development, the results of this thesis suggest that further research into how fostering institutional adaptability could be functionally represented to strengthen the framework’s efficacy in shaping potential policy interventions. Incorporating insights from “reflexive governance” literature, which advocates for adaptive and participatory approaches in policy-making, could provide critical insight as the nation looks to design and implement civil service reform supportive of innovation (Lindner et al., 2016).

The case study of Armenia's AI TIS illustrates that system transformation is a fundamentally social process, deeply influenced by the cultural and competency asymmetries between the Silicon Valley-influenced private sector and the Soviet-era public sector, as well as the critical role of government in serving as a platform to bridge these divides and foster productive dialogue. General consensus from the interviews was that, while it is steadily growing, one of the largest barriers to productive cooperation is lack of “trust” between actors (Interviews 2, 3, 4, 5, 6). As FAST’s VP for Strategic Programs lamented, “everyone wants the same thing, but different interpretations about how best to achieve it has produced unhealthy competition” (Interview 7). The results indicate that the private sector’s more agile culture often clashes with public institutions still entrenched in Soviet-era practices, with the government’s unreliable track record in fulfilling IS-building commitments perceived as a major obstacle. However, there is acknowledgement that “Armenia is not Switzerland”—capacity limitations are to be expected at this stage of the country’s development (Interview 7).

A relevant passage from *Recoding America* by Jennifer Pahlka (2023, p. 128) had circulated amongst members of the GPU advocacy coalition in a mutual Telegram group (Interview 5):

> “When systems or organizations don’t work the way you think they should, it is generally not because the people in them are stupid or evil. It is because they are operating according to structures and incentives that aren’t obvious from the outside.”

While the acknowledgement that bureaucrats are not "stupid or evil" is far from a significant development, it nevertheless signals a willingness to understand and align "structures and incentives" across different stakeholders within the system. This notion is further emphasized theoretically by Metcalfe (1994, pp. 933-934), who posits that:

> "Just as individuals operate under the constraints of localised, imperfect and uncertain information, so does the policy maker who must also contend with the limits set down by higher political authority. Options are constrained administratively and politically, policy makers operate with multiple objectives, and one cannot expect the policies which emerge to be independent of the processes by which they are formed."

This suggests that in order to affect system change, an indispensable element is "getting the policy process right" (Rodrik, 2004, p. 3)—offering further justification for the expanded definition of **F7** to include political legitimacy and institutional adaptability. This highlights the importance of considering "soft institutions" often overlooked in existing TIS frameworks (Bergek 2019). While these elements are challenging to model, failing to account for them limits the relevance and effectiveness of IS frameworks outside of the developed-country context in which they originated. Moving forward, the IS model must account for how these "soft institutions" function within each country's unique history and culture (Dyker and Perrin, 1997, Fagerberg and Godinho, 2002, Freeman, 2002) in order to be truly representative of the systemic dynamics shaping innovation and technological development.

Ultimately, these findings underscore the value of adapting the functions of TIS framework across diverse empirical cases, demonstrating its value as a "heuristic" approach for narrating the "story" of IS development rather than a rigid diagnostic tool (Hekkert et al. 2007, p. 414). While the success of the emerging AI TIS in catalyzing long-term economic growth in Armenia will only be determined in time, critically engaging with this chapter in its development has the potential to highlight how institutional "backwardness" can be as—if not more—significant as emerging "windows" of technological opportunity in affecting national economic catch-up.

CONCLUSION

This thesis opened with emphasizing the indispensability of innovation-based development and the role of IS models in promoting it. By introducing the Armenian case, it proposed a shift from the structure-based NIS approach to process-based TIS framework, while also suggesting necessary modifications for its applicability across diverse empirical cases. The theoretical section demonstrated how the TIS framework can better capture the functional processes involved in emerging TIS development during critical “windows of opportunity,” while addressing the conditions of fragmented transition NIS that may impede these efforts. Drawing on Abramovitz’ (1986) hypothesis that technological catch-up is contingent on “social capabilities” such as institutional adaptability, the results supported the theoretical claim that these factors, along with political legitimacy, must be incorporated into framework for it to accurately reflect the “virtuosity” of system-building efforts.

“Soft institutions” such as culture and trust must also be more explicitly represented in the functions of IS model. Only then can the framework reliably assess innovation dynamics and guide the implementation of effective policy reforms. While more comprehensive research is required to establish a more comprehensive account of the AI TIS’ objective performance, applying the adapted framework to the Armenian case facilitated a nuanced discussion of the dynamics involved in participating in a fast-changing global TIS; highlighting the significance of historical context in shaping supportive national policy interventions and difficulty of effectively modeling it. Although this approach successfully addressed the research problem of investigating dynamics within Armenia’s fragmented transition NIS and its capacity for technological catch-up, future avenues for research warrant further consideration.

Critiques of the TIS model often highlight its implicit assumption of the “desirability” of specific technologies (Markard et al., 2015, p. 82). Although high-tech innovation is often seen as inherently beneficial (Lindner et al., 2016, p. 8), emerging technologies can bring unintended consequences and potentially undermine other national development goals (Chaminade et al., 2018). As Nelson (2011) discusses in his revisited "Moon and the Ghetto" essays, the prevalence of advanced technological capability alongside persistent social issues is also relevant. In Armenia’s case, AI could amplify these inequalities, especially if there is no concerted effort to ensure the sector uplifts the rest of the economy (Acemoglu and Krikorian, 2024). The next "evolution" of innovation policy adopts a more "transformative" approach to address this development concern (Weber and Rohracher, 2012, p. 1042), acknowledging that high-tech innovation, on its own, does not guarantee broad societal benefit. Although demanding high-level capabilities, attention should still be paid to this new generation of IS-building, as overreliance on previous models like NIS and TIS may not be sufficient in meeting the challenges of sustainability transitions.

Just as "success stories" play a key role in guiding the search towards promising directions of technological change (Hekkert et al., 2007, p. 423), the same principle could be applied to institutional transformation. Further research into successful cases of institutional reform could provide insights into the drivers of adaptability, as well as the political conditions necessary for sustainable public sector innovation. One example is the Central Bank's recent digitization initiative and the role of the Information Systems Management Council, coordinated by the Deputy PM, which offer a valuable precedent for examining how policy alignment can enhance innovation strategies across government entities. The Central Bank's partnership with experts from Estonia serves as an example of the value of policy learning rather than emulation (*"Armenia is setting,"* 2022), and further research could inform and empower similar initiatives across the public sector.

Ultimately, it is reasonable to expect that the "long, uncertain, and painful process" of building an emerging TIS (Jacobsson and Johnson, 2000, p. 630) within the context of a "slow, messy, and disappointing" NIS transition (Pavitt, 1997, p. 43) would live up to its arduous reputation. The challenges faced in developing the emerging AI TIS in Armenia should—by nature—reflect growing pains rather than signal systemic failure. As Freeman (2002, p. 208) noted, however, "some of the most promising lines of future research on national systems would appear to be in the study of catch-up failure and falling behind in economic growth." Whether Armenia rises to the challenge of technological transformation or becomes a cautionary tale of arrested development will depend on its ability to turn system pain points into opportunities for growth, rather than stagnation.

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APPENDICES

Appendix 1. RA Innovation Policy 2000-2023

2000	Law on Scientific and Technological Activity	Objective to regulate interactions among those conducting R&D, government entities, and end users of R&D results, outlining general principles for shaping and executing state science and technology policy
2002	Science and Technology Development Priorities	Included Armenian studies, basic research promoting applied research, special-purpose research, information technologies, advanced technologies (biotech, nanotech), new energy sources, risk factors and human health, new materials
2002	Enterprise Incubator Foundation (EIF)	Established with the World Bank to foster ICT sector growth through innovation, technological advancement, and support for business development
2005	Concept of Innovation Activity	Sets principles for state policy, fostering a NIS to boost sustainable development, competitiveness, and create favorable environment for international economic cooperation
2006	Law on State Support to Innovation Activity	Assigns MoE to formulate and execute national innovation policy, focusing on prioritizing high-tech advancements and providing state support for innovation activities
2007	Conception on Improvements in Science	Objective to create knowledge-based economy, increase science funding and clarify funding mechanisms
2007	Creation of State Committee of Science	Established to lead/carry out S&T policy, responsible for developing national research programs
2009	Creation of the National Center for Innovation and Entrepreneurship (NCIE)	Established to facilitate technology transfer, provide support services to SMEs, and provide scientific and technical information and library services
2010	Resolution on the Priorities of Science and Technology Development for 2010-2014	Identified six areas, including IT and advanced technologies (biotech, nanotech, etc)
2010	Strategy of Science Development	Envisioned that by 2020, RA would have internationally-competitive, science-based economy
2011	Law on the National Academy of Sciences	Classified NAS as self-governing, special status scientific non-profit
2011	Initial Strategy for the Formulation of an Innovative Economy	Aimed to position Armenia as “global center for R&D,” infrastructure-focused
2014	Science and Technology Development Priorities for 2015-2019	Defines science and technology priorities, including renewable energy, advanced technologies, IT, and space sciences

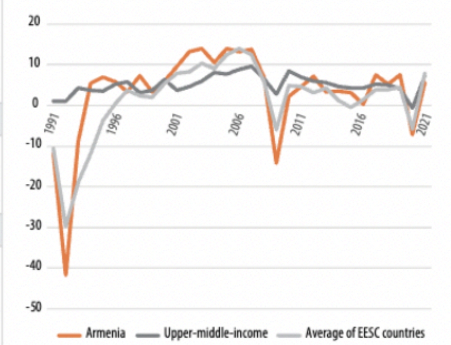
2016	Armenia joins EU "Horizon 2020" Program	Enabled local researchers and innovators to participate in EU's international research and innovation funding framework
2017	Science Sector Development Strategy for 2017-2020	Aimed to enhance Armenia's technological growth by fostering innovation, improving R&D infrastructure, and enhancing collaboration between academia and industry
2019	Ministry of High-Tech Industry (MoHTI)	Reconceptualized the existing Ministry of Transport, Communication, and Information Technologies to focus on advancing technological innovation and support high-tech sector development, reformed tax code to support ICT companies
2018	Engineering City	Established with World Bank funding, created a space for engineering companies in the high-tech sector with the purpose of facilitating and accelerating the development of complex engineering solutions
2020	Small and Medium-sized Entrepreneurship Development Strategy 2020–2024	Aimed at strengthening the entrepreneurial environment for SMEs, supporting skill development and facilitating access to financial resources, with the overall goal of improving SME productivity and promoting an entrepreneurial culture
2021	Digitalization Strategy 2021–2025	Fosters the digital transformation of the Government, the economy and civil society by introducing innovative technologies, enhancing cybersecurity, strengthening data policy and e-government systems, coordinating digitization processes and creating common standards
2022	NCIE charter resolution	Updated mandate to include attracting "highly qualified specialists"
2022	On State Support For The Promotion Of The High Technology Sector	Aims to foster balanced and sustainable development, technological re-equipment, and innovation infrastructure, promote foreign economic activity by providing state support to individuals and organizations in the high-tech sector, including amendments to the tax code
2023	Academic City (proposed)	Infrastructure project aimed at fostering innovation and research by establishing a hub for higher education, scientific research, and technological development outside of Yerevan, relocating existing state institutions

Sources: Danielyan (2008); Khnkoyan (2012); Poghosyan (2017); UNECE (2023)

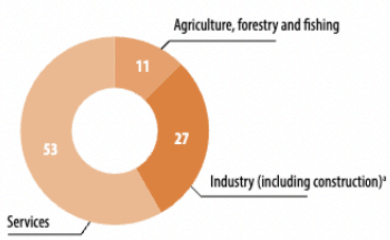
Appendix 2. RA Basic Macroeconomic Indicators

Population	
Total (millions), 2022	2.9
Capital city: Yerevan (millions), 2022	1.1
Urban (per cent of total), 2022	63
Natural resources	
Land area (square kilometres), 2022	29
Agricultural land (per cent of land area), 2022	69
GDP	
At current prices ($ billion), 2021	13.9
Per capita, PPP (current international $), 2021	15,593
Average annual growth (2010–2021)	5.9

GDP growth, annual (per cent), 1991–2021



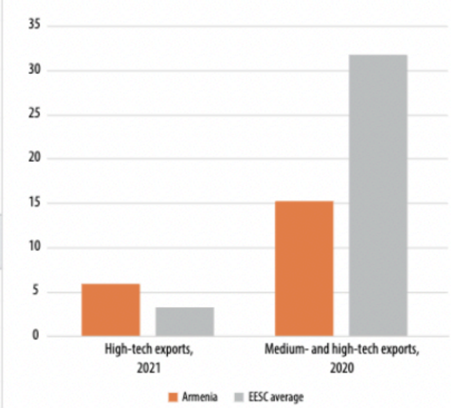
Value added (per cent of GDP), 2021



Private sector	
Share of SMEs[b] (per cent of total enterprises), 2019	99.8
Private sector SME[b] contribution to GDP (per cent), 2019	65.4
Share of SMEs in employment (per cent of total employed), 2019	69.7
New business density (new registrations per thousand population ages 15–64), 2020	2.9
Labour market	
Employment rate (per cent of total population ages 15+), 2021	54
Unemployment rate (per cent of total labour force), 2021	15.5

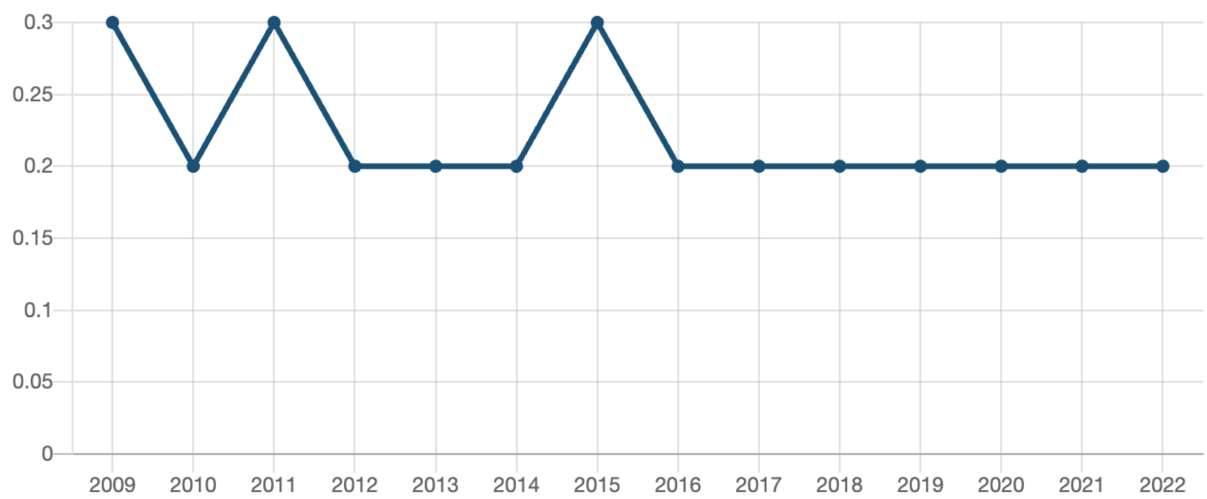
Trade	
Exports and imports ($ billions)	
Exports of goods and services (per cent of GDP), 2021	35.3
Imports of goods and services (per cent of GDP), 2021	43.8
Trade balance (per cent of GDP), 2020	-11.1
High-tech exports (per cent of manufactured exports), 2021	6
Major export markets (per cent of exports), 2019	
Russian Federation	27.5
Switzerland	17.5
Bulgaria	7.9
China	7.4
Iraq	6.8

High- and medium-tech exports (per cent of manufactured exports), 2020 and 2021



Source: UNECE (2023, p. 4)

Appendix 3. RA Research and Development Expenditure (% of GDP)

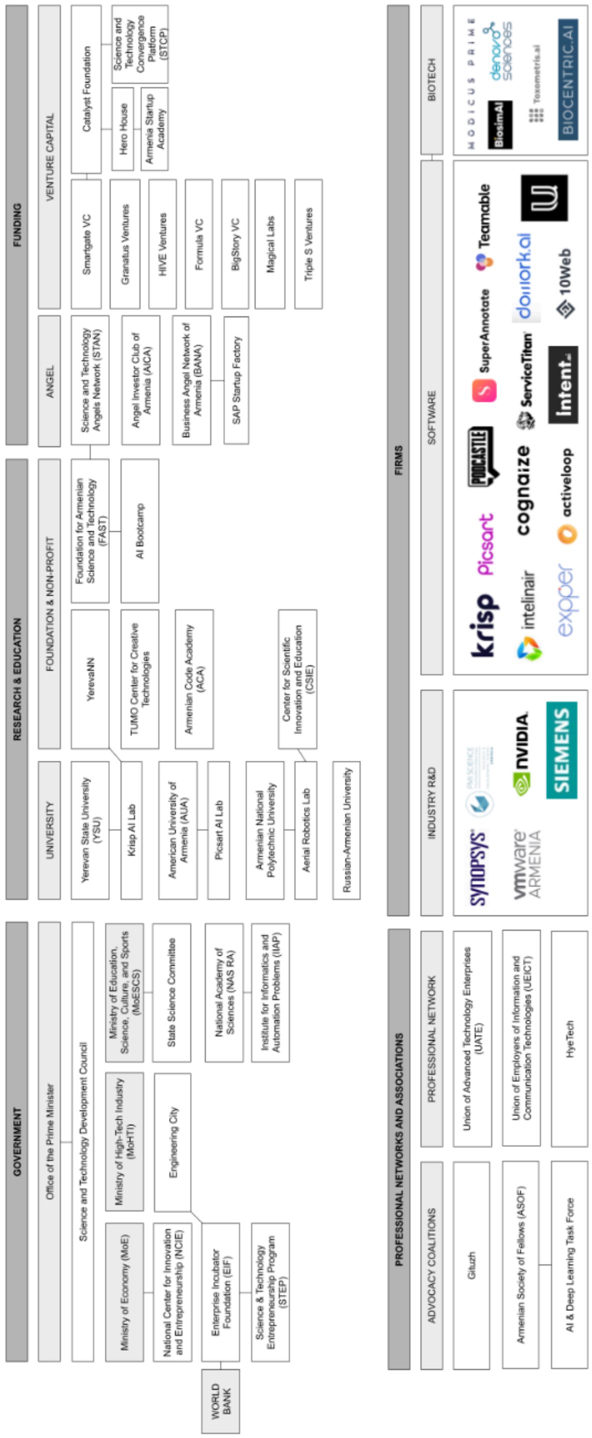


Source: UNECE (2023)

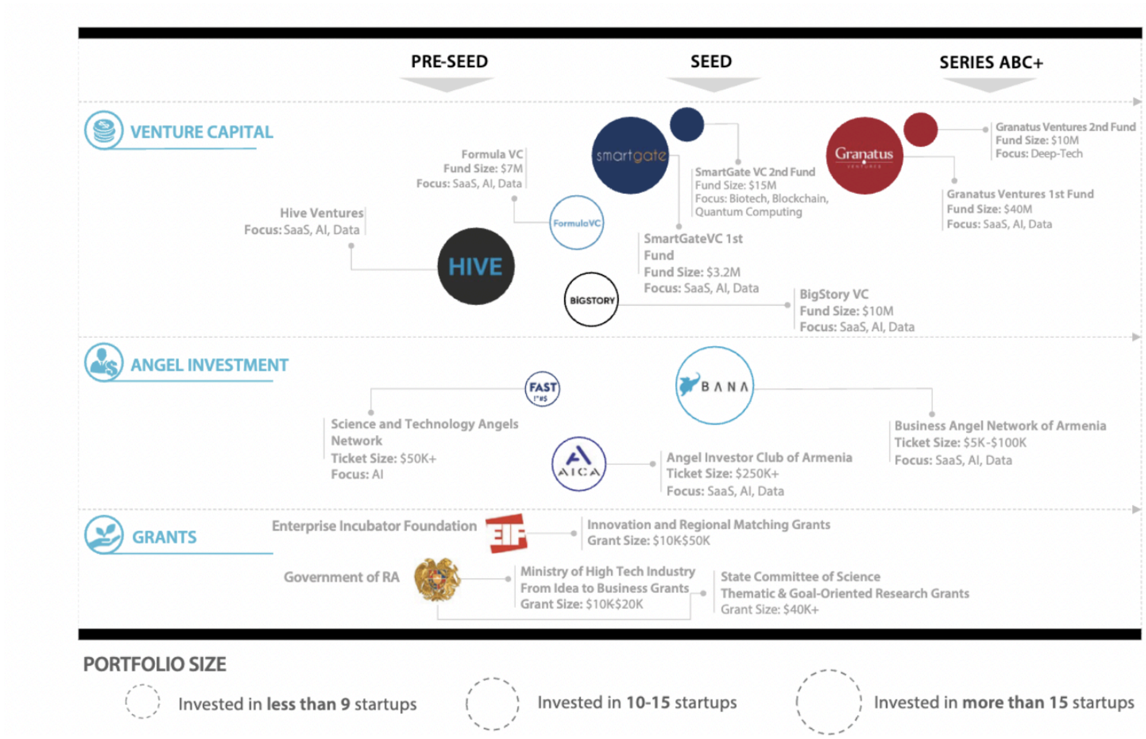
Appendix 4. RA Global Innovation Index

Source: WIPO Global Innovation Index (GII) (2024)

Appendix 5. Structure of RA AI TIS



Appendix 6. RA Innovation Funding Landscape Overview



Source: UNECE (2023, p. 73)

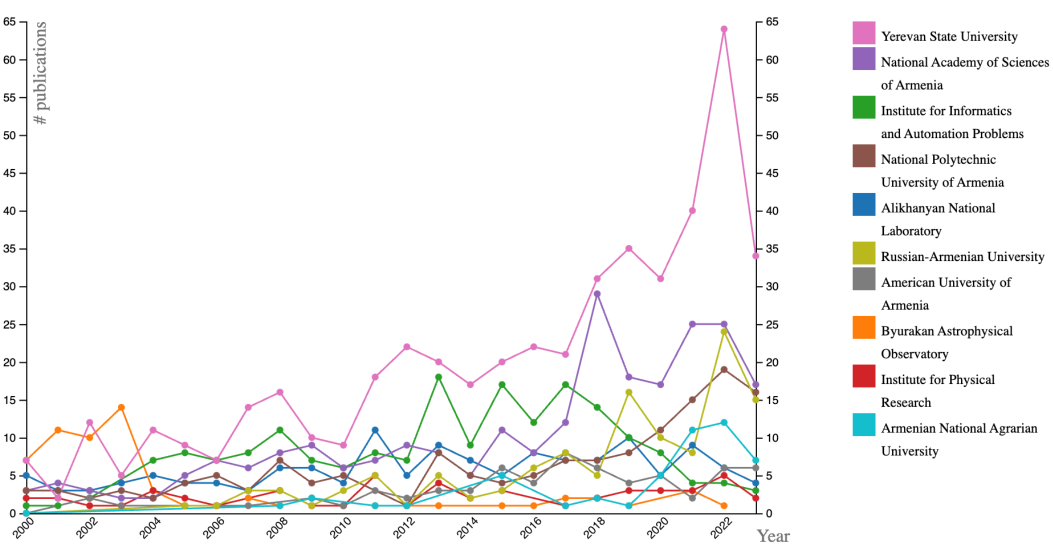
Appendix 7. Leading Armenian AI Companies

	company	description	funding
2011	Picsart	AI-powered creative platform for photo and video editing	$195M
2012	ServiceTitan	software solutions to streamline operations for trades and home service businesses	$1.1B
2016	IntelinAir	AI-powered crop analytics to optimize agricultural decisions	$24.9M
2017	Krisp	AI-based noise cancellation for clear voice communication	$17.5M
2017	Exxper Technologies	AI-driven robots for emotional support in healthcare	$10M

2017	10Web	AI platform for creating and optimizing WordPress websites	$4M
2018	SuperAnnotate	AI-powered tools for annotating and managing large-scale datasets for computer vision projects	$48.5M
2020	Podcastle	AI-enabled audio and video content creation and editing	$22.3M
2020	Activeloop	enterprise AI software to manage unstructured data and extract insights	$19.6M
2020	Denovo Sciences	AI for multitarget drug discovery and optimization	$125K
2020	Modicus Prime	AI for biologics image analysis and quality control	$4.7M
2021	Cognaize	AI-based financial document data extraction	$20M
2021	Biosim AI	Accelerates drug discovery using AI and molecular simulations	$12.3M

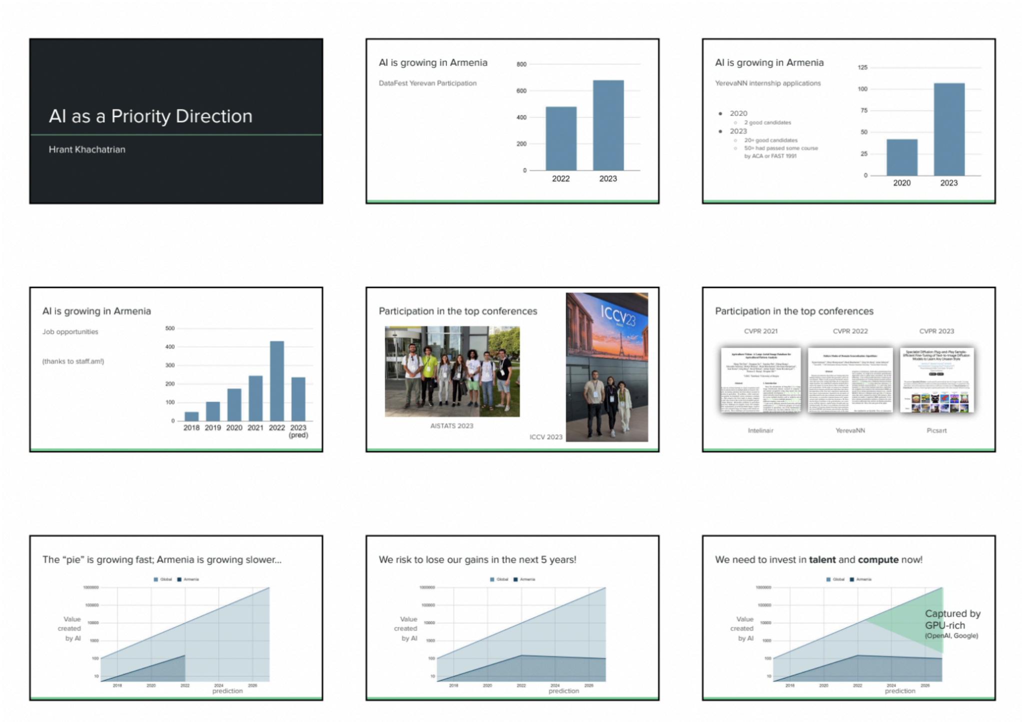
Source: adapted from Crunchbase (2023)

Appendix 8. AI Research by Institution



Source: OECD.AI (2023)

Appendix 9. YerevaNN Digitec Presentation



Source: YerevaNN (2023)

Appendix 10. FAST Generation AI one-pager

Generation AI
Nurturing Future Innovators

BRINGING COMPETITIVE AI EDUCATION TO ARMENIA

In an ever-evolving digital landscape, the rapid advancements in Artificial Intelligence (AI) have reshaped industries, transformed economies, and revolutionized the way we live and work. Countries worldwide are recognizing AI's role in driving innovation, competitiveness, and sustainable growth.

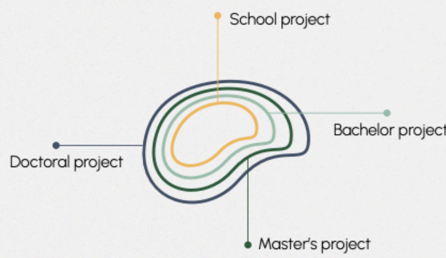
Like many countries, Armenia is dealing with a lack of AI expertise, despite its rich heritage in mathematics and computer science. By leveraging this untapped potential, it could bring about substantial change for future generations.

The Foundation for Armenian Science and Technology (FAST) is dedicated to establishing a sustainable educational pipeline to prepare professionals ready for an AI-enhanced future. Our strategy aims to stimulate local AI sector growth, meet global needs, and lead innovations in the field.

GENERATION AI: NURTURING FUTURE INNOVATORS

FAST has joined forces with the Ministry of Education, Science, Culture, and Sports to implement Generation AI, a pioneering multi-stage program with the aim of creating a continuous educational path that identifies and nurtures young minds from high school through to university and beyond.

Through this strategic partnership, as well as with active involvement of NGOs, academia, and industry professionals, we aim to bring systemic change in the Armenian education system on every step along the way to create an educational and career pipeline of AI researchers and innovators.



GENERATION AI: HIGH SCHOOL PILOT PROJECT

The Generation AI: High School Project is the driving force behind the entire initiative, providing the foundation for the planned scaling. The high school stage will introduce a special curriculum and teaching methodology to prepare students for further education and careers in AI and related fields.

With this approach, we're laying the groundwork for breakthroughs in AI, along with its integration into emerging fields like Biotech, Bioinformatics, Material Sciences, Cheminformatics, Robotics, and Cybersecurity.

16 Participating Schools

40+ Teachers and Instructors

7 Regions across Armenia

400+ Students in the 10th grade

OUR CORE ACTIONS

- Development of Math, Computer Science (Python), and AI curricula and educational resources.
- Recruitment and development of competent teaching staff and bringing members of the industry and academia to schools.
- Implementation of career guidance and English enhancement programs.
- Upgrades to school informatics labs facilities.
- Designing a scale-up strategy for collaborative, government-aligned implementation.

OUR PARTNERS AND SUPPORTERS

At FAST, we position ourselves not merely as an organization, but as a dynamic platform fostering global Armenian collaboration. Through our programming, our primary objective is to consolidate knowledge found within Armenia and our extensive network, creating a unified powerhouse of intellect and innovation.

In pursuit of our ongoing commitment to empower young Armenian talent, we recognize the importance of collective effort. We extend an invitation to you to join us today, to collaborate with a diverse, global community dedicated to advancing the field of AI for the betterment of one nation while contributing positively to societies worldwide.

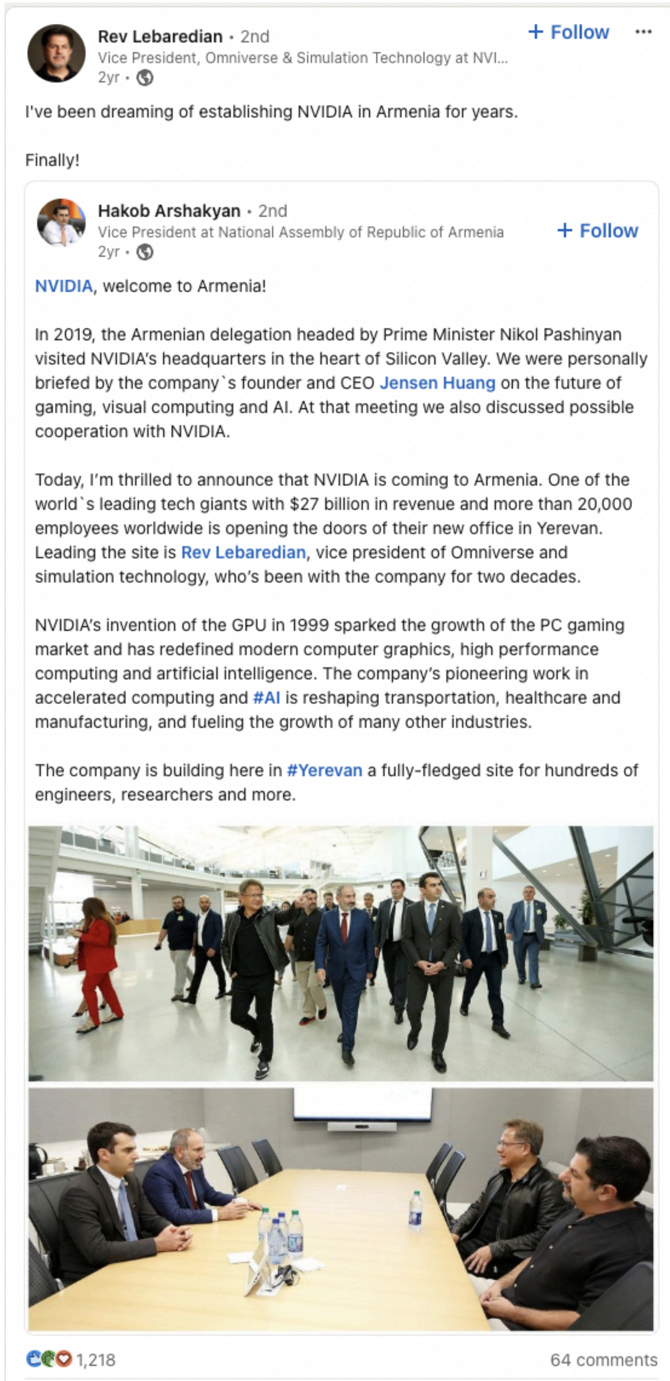
Developed and Implemented by FAST Discovering the Future

Strategic Partner THE MINISTRY OF EDUCATION, SCIENCE, CULTURE AND SPORTS OF THE REPUBLIC OF ARMENIA

fast.foundation
education@fast.foundation
+374 60 74 00 44

Source: FAST (2023)

Appendix 11. NVIDIA Armenian R&D Center Announcement



Rev Lebaredian • 2nd
+ Follow
Vice President, Omniverse & Simulation Technology at NVI...
2yr •

I've been dreaming of establishing NVIDIA in Armenia for years.

Finally!

Hakob Arshakyan • 2nd
Vice President at National Assembly of Republic of Armenia
+ Follow
2yr •

NVIDIA, welcome to Armenia!

In 2019, the Armenian delegation headed by Prime Minister Nikol Pashinyan visited NVIDIA's headquarters in the heart of Silicon Valley. We were personally briefed by the company`s founder and CEO Jensen Huang on the future of gaming, visual computing and AI. At that meeting we also discussed possible cooperation with NVIDIA.

Today, I'm thrilled to announce that NVIDIA is coming to Armenia. One of the world`s leading tech giants with $27 billion in revenue and more than 20,000 employees worldwide is opening the doors of their new office in Yerevan. Leading the site is Rev Lebaredian, vice president of Omniverse and simulation technology, who's been with the company for two decades.

NVIDIA's invention of the GPU in 1999 sparked the growth of the PC gaming market and has redefined modern computer graphics, high performance computing and artificial intelligence. The company's pioneering work in accelerated computing and #AI is reshaping transportation, healthcare and manufacturing, and fueling the growth of many other industries.

The company is building here in #Yerevan a fully-fledged site for hundreds of engineers, researchers and more.

1,218
64 comments

Source: Linkedin (2023)

Appendix 12. AI Supercomputing Center Announcement

Hakob Arshakyan
November 30, 2023

Հայաստանում կստեղծվի Արհեստական բանականության սուպերհամակարգչային կենտրոն: Կենտրոնի ստեղծման ֆինանսավորումը կկազմի 3,5 մլրդ ՀՀ դրամ (շուրջ 8,5 մլն ԱՄՆ դոլար): Այն առաջինը կլինի մեր տարածաշրջանում,և հիմնված է ամենաժամանակակից տեխնոլոգիաների վրա:

Այս ծրագիրը ՀՀ Վարչապետ Nikol Pashinyan / Նիկոլ Փաշինյան ի և #NVIDIA ընկերության հիմնադիր և գործադիր տնօրեն Ջենսեն Հուանգի ապրիլի 21-ին Երևանում տեղի ունեցած հանդիպմանն արձանագրված առաջնահերթության իրականացումն է:

Որպես ԱԺ նախագահի տեղակալ՝ Արհեստական բանականության սուպերհամակարգչային կենտրոնի ծրագիրն առաջարկել եմ ընդունել 2024 բյուջեի մասին օրենքի նախագծում, որը քիչ առաջ հաստատվեց Կառավարության նիստում, և շուտով կքննարկվի Ազգային ժողովում:

Ցանկանում եմ շնորհակալություն հայտնել բոլոր այն անձանց, գիտնականներին, ձեռներեցներին, պետական պաշտոնյաներին, ովքեր մասնակցեցին ծրագրի նախապատրաստական աշխատանքներին:

#AI #Supercomputing center will be established in #Armenia. The total budget for the Project is around $8,5M. It will be the first in our region and is based on the latest #technologies.

This program is the implementation of the #priority recorded during the meeting of the #PM Nikol Pashinyan and the #Founder and #CEO of NVIDIA Jensen Huang that took place months ago in #Yerevan.

As the Deputy Speaker of the National Assembly, I proposed to adopt the program of the #Artificial #Intelligence #Supercomputer #Center in the 2024 budget, which was just approved by the #Government, and will soon be discussed in the #National #Assembly.

I would like to thank all those people, scientists, entrepreneurs, government officials who participated in the preparation of the project.

Source: Facebook (2023)

Appendix 13. RA Science and Technology Development Council Announcement

Hakob Arshakyan · 2nd
Vice President at National Assembly of Republic of Armenia
10mo · Edited ·

+ Follow

Under the leadership of the #Prime #Minister of the Republic of #Armenia, #Science and #Technology #Development #Council of #Armenia was established.

The goal of the #Council is to contribute to rapid #Scientific and #Technological development of #Armenia and #Transformation of Armenia into a #High_tech, #Industrial #Country.

Members of the Council:
Prime Minister of the Republic of Armenia (Chairman),
Deputy PM of the RA,
VP of the National Assembly, Hakob Arshakyan,
Chief of Staff of RA PM office,
Minister of Education, Science, Culture and Sport,
Minister of High-Tech Industry (Secretary),
Minister of Economy,
Chairman, Standing Committee on Science, Education, Culture, Diaspora, Youth and Sport of the NA of the RA,
Chairman, Committee on Higher Education and Science of the MESCS,
President, Defense-Industrial Committee of the MHTI,
President, National Academy of Sciences, RA(NASRA),

Yervant Zorian - Doctor of Sciences, Professor, Chief Architect and Fellow at Synopsys, President of Synopsys Armenia, Fellow (IEEE), President of IEEE Test Technology Technical Council (TTTC), Board Member, (AGBU),
Israelian Garik - Doctor of Physico-Mathematical Sciences, Institute of Astrophysics of the Canary Islands (Spain), founder STARMUS Festival,
Hovig Safoian - SADA Systems, Co-founder and Chairman of the Board,
Al Eisaian - Cognaize, CEO and board member, INtelinAir, founder,
Ashot Hovanesian - #AmCham, board member, Synergy International Systems, founder, CEO,
Karén Gyulbudaghyan - Strategic Value Ventures, founder, Berkeley SkyDeck, Ambassador, Advisor
Ardem Patapoutian - The Nobel Prize winner, Doctor of Biological Sciences, molecular biologist, fellow of the American Association for the Advancement of Science,
Sam Simonian - Tumo Center for Creative Technologies, cofounder, AGBU Council of Trustees,
Mary Papazian - Former president of San Jose State University, former president of Southern Connecticut State University,
Felix Aharonian – Astrophysics, foreign member of the NAS RA, Professor at the Dublin Institute for Advanced Studies (DIAS), laureate of the scientific grant of the President of China,
Seyran Minasyan - Director of the Institute of Chemical Physics after A.B. Nalbandyan, NASRA,
Aram Papoyan - Doctor of Physico-Mathematical Sciences, Corresponding Member of the Presidium, NASRA, Institute for Physical Research NASRA, Director.
Ani Aprahamian - Nuclear Physicist, Professor of Physics at the University of Notre Dame, Foreign member of the NASRA,
Garo Armen - Doctor of physical chemistry, Chairman & CEO at Agenus, founder and chairman of the Children of Armenia Fund (COAF),
Vardan Aleksanyan - @Engineering Association, Director, Project Integration, CEO
Armen Baldryan - UEICT (Union of Employers of Information and Communication Technologies), Chairman,
Arsen Baghdasaryan - Union of Advanced Technology Enterprises (UATE) Board member, DataArt, VP.

Congratulations! Looking forward to our first meeting!

235 · 13 comments · 17 reposts

Source: Linkedin (2023)

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