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Development of a New Technological Paradigm in the Arctic Regions in 1990–2021

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Abstract. Research on the evolution of technological paradigms in various countries should be continued at the level of regions and municipalities. The article fills the gap, as its purpose is to study the formation of a new technological paradigm in the Arctic zone of the Russian Federation. We identified the chronology of the new technological paradigm deployment in the Russian Arctic over the past three decades; explained the reasons for making Nenets Autonomous Okrug a pilot site for technological, organizational, institutional experiments and innovations in the Arctic zone; we characterized factors impeding and promoting the formation of a new technological paradigm in the Murmansk Oblast. We determined the methods of research (system-wide approach, retrospective, cartographic, comparative, structural analysis) depending on the chosen theoretical and methodological framework: the theory of techno-economic paradigms, the theory for economic development of the North and the Arctic, the concept of evolutionary economic geography. As a result, we have identified and characterized five stages in

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the formation of a new technological paradigm in the Arctic in 1990–2021. We use the data on Nenets Autonomous Okrug to show the favorable role of small and medium-sized natural assets and the organizational diversity of extractive companies, an active policy of the regional government that pursues the principles of constructive duality at the first stage of the formation of the new technological paradigm. We also consider the data on the Murmansk Oblast to show the role of the resource monopoly of local large mining enterprises in inhibiting the entry of new actors and the deployment of new projects in the mining development of the region. We conclude that the formation of the new technological paradigm in the Arctic regions is characterized by significant unevenness (asynchrony): the susceptibility of the Arctic territory to the arrival of new actors, technologies and institutions is determined by the age of the resource province, type of natural resource, size and forms of location of the main deposits. The most important task for future research is to study optimal forms of state influence on the development of a new way of life in the territories of the Arctic with tools and institutions of active industrial policy at the federal, regional and municipal level.

Key words: formation of a new technological paradigm, regions of the Russian Arctic, Nenets Autonomous Okrug as a pilot development area, Murmansk Oblast as an old industrial region, pilot project, marine logistics, technological innovation.

Introduction

To date, the topic of national techno-economic dynamics and transition to a new technological paradigm of the leading countries is relatively well developed in the world. The efforts of C. Freeman (Freeman et al., 1982; Freeman, Perez, 1988; Freeman, 1987), C. Perez (Perez, 2010), S. Glaz'ev (Glaz'ev, 1993; Glaz'ev, 2012) and other scientists developed the ideas of Kondratiev waves (Kondratiev, 1925) in the form of a comprehensive picture of the conjugate technological, economic and socio-cultural (institutional) dynamics that accompanies the transition to the new technologies and organizational principles of economic activity, showing the features of the stages of origin, formation and expansion of a new techno-economic paradigm in the economy of leading countries of the world.

However, the problem of applying the concept of technological paradigms to the particular local economic, social and natural features has not been solved. For Russia, due to the huge interregional contrasts and differences, it is of great importance and relevance. Consideration of the local context is especially important in the first stages of the establishment of a new technological paradigm, when territorial differences are exceptionally large (then, with its subsequent spatial expansion, the situation evens out).

The task is not only to change the optics from telescope to microscope while studying the formation of a new technological structure in the Arctic regions. It is very important to pay attention to the properties of the regional space as an environment for the dissemination of technological innovations and other attributes of the new technological paradigm. The settlement system, infrastructure of regional space, territorial structure of economy, qualitative characteristics of local communities, and for the Arctic territories – and the age in decades of economic development – determine different degrees of permeability of regional space to innovations[1]: in one case they act as a catalyst for the diffusion of innovation, in another, on the contrary, as a filter and a brake (barrier) of radical innovative modernization.

[1] A complex phenomenon that depends on landscapes, settlement systems, infrastructure, institutions of power, and socio-cultural characteristics of local communities.

The context of the regional space and its various properties in terms of permeability to technological innovations disappears in both the panoramic country view (macro-level) and the intra-corporate view (micro-level). Paradoxically, against the background of numerous studies of the innovation process in the country and corporations, there are almost no works on the "context", on the environment for a new paradigm deployment in the form of particular regional spaces. However, it is in the Arctic that this environment is exceptionally specific and certainly deserves separate consideration in the context of studying the spread of the new technological paradigm. Our study aims to fill this gap.

The subject of the study is the process of spreading the new technological paradigm in regional spaces over the past 30 years, which is considered on the particular object – the regions of the Arctic. The purpose of the work is to study the features of the formation of a new technological paradigm in the Russian Arctic. It provides for the solution of three tasks: 1) to determine the chronology of the deployment of the new technological paradigm in the Russian Arctic in the last three decades; 2) to characterize Nenets Autonomous Okrug as an area of new economic development and a pilot site for the formation of the new technological paradigm in the Arctic and determine the reasons for its nomination for this role; 3) to determine the sequence of formation of the new technological paradigm in the old industrial Murmansk Oblast, catalysts and blockages of this process.

Methodology and methods

The formation of a new technological paradigm in the Arctic is considered in this paper as a process of penetration of new technologies in the development of resources and spaces, which depends on the regional environment, the susceptibility of which to innovation is determined by the activities of regional authorities in the field of industrial policy and the system of its relations with the federal center, major corporate actors in the region, local manufacturing businesses.

Three sources represent the theoretical and methodological foundation of the study. First, it is the concept of techno-economic paradigm, formed for the level of countries in recent decades by the works of numerous supporters and followers of Kondratiev waves theory. The methodology of evolutionary economic geography, which emphasizes the deployment of the process in the regional space, allowed performing the tasks of adapting this country concept for the Arctic regions, taking into account their significant specificity in the resource profile, low population, transport periphery and natural extremes.

Second, it is the theory of economic development of the North and the Arctic. For many decades, it has been developed by Soviet and Russian economist-geographers. It provides a constructive link between the techno-economic non-spatial concept of paradigms and the very specific properties of the regional space of the Russian Arctic: the establishment of a new technological paradigm in the Arctic is naturally associated with a new cycle of development of resources, land and sea spaces. The features of the methods we use (retrospective analysis, cartographic, comparative, etc.) are determined by the legacy of the development school.

The third theoretical and methodological source is the holistic approach. The authors proceeded from the fact that the formation of a new technological paradigm is associated with the implementation of not just one, but numerous related innovations along the entire resource chain.

Main results

Five stages of deployment of the new technological paradigm in the Russian Arctic

In 1992, along with a radical market reform in Russia, began the first, initial period of "groping" technological and organizational innovation in the

development of the Arctic. At this time, the new paradigm was being "hatched" in the cocoon of the old one: as a result of corporatization, privatization and fragmentation of dozens of large state mining associations, chapters and enterprises, a new experimental environment for testing potential new ways of techno-economic development of the Arctic was emerging.

The significance of the reform for the basic extractive industries in the Arctic was that it opened up the opportunity for people from outside the extractive industry – from geology, the financial sector. In doing so, they could get a chance for risky entrepreneurship and free capital to try new technical and organizational solutions.

Some leaders of Soviet mining, oil and gas enterprises also proved capable of revolutionary technological and organizational experiments. However, the technological revolution in the Arctic in the 1990s was mostly started by specialists from outside the production system, such as young, enterprising financiers.

The paradox of the technological revolution that began in the 1990s was that its success required not only new technology, but also investors with a new mindset. Technologies were developed, used, but did not lead to revolutionary transformation: moreover, the new technologies themselves often reinforced the dependence on the former industrial path.

Financial capital and its carriers, as Carlota Perez (Perez, 2011) notes, due to their mobility, unrootedness, openness to the established decades-long production and technological path[2], ensured the loosening of the old paradigm and conditions for a radical renovation of extractive production – the transition to new technological schemes, solutions, resources. The reform has shaped the conditions (new regime of production sharing agreements (PSA), new joint ventures (JV), small and medium resource enterprises, etc.) for new, non-state sources of free financial capital, private foreign investment and emerging new Russian investors in the Arctic mining industry.

The particular forms of private financial capital coming into the Arctic's mining assets were manifold: in one case, young specialists became financial managers and gave their first accumulated capital to investments in high-margin resource businesses (for example, Norilsk Nickel); in another case, private capital came in the form of a joint venture, where the Russian co-director was responsible for production competencies and the foreign co-director was responsible for financial capital and financial competencies (Cyprus Minerals JV at the Kubaka deposit in the Magadan Oblast); in a third case, a foreign specialist – responsible for foreign investment – was invited to the board of directors of a Russian arctic corporation.

The key event of the first period of "groping" for the contours of the new technological pattern in the extractive industry of the Russian Arctic, which ended in 1998 with the global financial and economic crisis, was a large-scale experimentation in Nenets Autonomous Okrug (NAO), the area of pioneering development of oil and oil-and-gas fields.

The next period, which began in the crisis year of 1998, was marked by the reintegration of technologically interconnected mining operations in the Arctic under the auspices of new private vertically integrated resource companies. PJSC Lukoil and PJSC MMC Norilsk Nickel, updating the principles of maritime logistics, implemented at this time large-scale programs for the construction of reinforced ice-class vessels.

[2] Financial capital is mobile because it is not tied to specific productive knowledge. During stationary periods, this is often a disadvantage, but during periods of technological revolutions it becomes a huge advantage: productive capital is rooted in a specific geographic region, a specific field of technical and engineering knowledge. After decades of success, it is difficult for capital to overcome its dependence on the path in times of technological revolutions. Not surprisingly, therefore, it is financial capital and its carriers that play a pioneering role here.

It was during this period, after corporatization of the solutions found, creation of new and privatization of state-owned mining enterprises, that another important process began to unfold on a large scale, namely renewal of the traditional mining industries of the old industrial regions of the Arctic by switching to new technologies, often with a partial change of the former resource profile (from placer gold to ore gold in Chukotka Autonomous Okrug, to greater extraction of palladium, copper in the Norilsk ore, etc.).

The global financial and economic crisis of 2008 was the time when the previous stage of the formation of a new techno-economic paradigm, relying on the energy of newly created private vertically integrated companies, and the beginning of the stage of strengthening state corporate structures of development, which were the main actors in replicating the innovations of the fifth Kondratiev wave in the Arctic. It was during this period of separation of Gazprom Neft from PJSC Gazprom, delimitation of the regulatory and statutory reinforced Arctic from the weakly regulatory protected North, refusal to develop the Shtokman field and putting the Prirazlomnaya[3] offshore ice-resistant platform into production that the contradictions of new and old technological and organizational solutions in the development of the Russian Arctic sharply increased. For example, between the Prirazlomnaya and Novy Port projects, which rely on offshore logistics, on the one hand, and the Bovanenkovo field development project, which relied on the traditional pipeline scheme of gas transportation that had been tested since the 1970s.

The year 2014 marked the end of the previous and the beginning of a new stage in the formation of the fifth Kondratiev wave in the Russian Arctic. The commissioning of the first LNG, Novatek's Yamal LNG project and the exponential growth of transportation volumes along the Northern Sea Route became a sign of aggressive establishment and victory of the new technological paradigm with its basic features: platform technologies of production and processing, shift work organization method, offshore logistics and remote control technologies.

Technological, organizational, institutional and even climate changes in this period "spurred" each other and provided establishment of a new format of advanced economic practices, advanced solutions in the form of the Yamal LNG project and the associated new port of Sabetta. It was during this period that the new technological paradigm showed its real strength *(Table)*, although it has not yet been fully implemented.

The new technological way manifests itself in the new nature of the economic development of the resources and spaces in the Arctic, i.e. it is a transition to the development of either new natural resources in the old development areas, or new land and sea areas, where previously exploited natural resources are extracted, or new in the square, that is, the development of new resources in new spaces[4]. To move to a more concrete understanding of the mechanisms and key actors of the new technological mode establishment in the Arctic, it is necessary not zonal, on the scale of the entire Arctic zone of Russia, but the regional level of specific Arctic territories.

Nenets Autonomous Okrug – pilot site for deployment of a new technological paradigm in the Russian Arctic

In the first decade of Russia's reform, NAO became an area of pioneering economic development in the Russian Arctic and a place to introduce technological, organizational, institutional innovations, methods of socially responsible and

[3] The prolonged postponement of the commissioning of the Prirazlomnaya project, apart from subjective reasons, can also be assessed more broadly – as the inability earlier than the 2000s to enter a new technical and economic paradigm in the extractive industry of the Russian Arctic.

[4] All schemes for the development of resource projects in the Arctic are described in detail in the article (Pilyasov, Putilova, 2020).

Stages of deployment of the fifth technological paradigm in the Russian Arctic

	Period				
	1980–1992	1992–1998	1998–2008	2008–2014	2014–2021
		Establishing a new paradigm			
Correlation of features of the old and new paradigm	Elimination of the old things	"Hatching" the new: the old is "bigger" than the new. Solo innovations. *The first innovators-entrepreneurs*. Opposition to the new in the form of resistance to reform. NAO is at the center of development innovations.	The old and the new are balanced. First attempts to cluster innovation (mining, processing, logistics). *Corporate imitators of innovators-entrepreneurs*. NAO is in the center of development innovations.	Setting a new paradigm: The new is "bigger than" the old. The clustering of innovation. *Second wave state corporate imitators*. The beginning of the sharp divergence of old and new development in the Arctic, greenfield and brownfield projects. NAO is in the center of development innovations.	Explosive growth of the new: the new suppresses the old. Fracture into pipe gas and LNG production zones. Strong economic and social polarization and sharp contrasts of the new and the old. *Aggressive establishment of a new paradigm.* Yamalo-Nenets Autonomous Okrug (YNAO) and Chukotka Autonomous Okrug (ChAO) are in the center of development innovations.
Key Events	Resource crisis in the old industrial areas of the Arctic and the North	Denationalization (fragmentation) and privatization of state industrial enterprises. The search for new production and logistics solutions by new economic actors. Dismantling and restructuring of old infrastructure in the form of small railroads, airfields, port points, single-industry settlements, etc. Pioneering new organizational (PSA), manufacturing and marine logistics solutions by small and medium-sized enterprises in NAO.	Corporatization of key natural assets in the Arctic. Start of transition to offshore logistics for large greenfield projects (Lukoil's Varandey Fixed Offshore Ice-Resistant Offloading Terminal (FOIROT) as a pilot project). Continued dismantling and restructuring of the infrastructure of the former industrial development.	State corporatization of maritime development of the Arctic. Shelf mania for the acquisition of license areas by state-owned companies. Start of experiments with smart marine logistics and platform production technologies by Gazpromneft in the Novoportovskoye (YNAO) and Prirazlomnoye (NAO) projects. Beginning the development of the Bovanenkovskoye field (YNAO) in the old southern pipeline export scheme and the Mayskoye gold deposit (ChAO) on new production technologies and old logistics schemes. Development of the Kupol deposit (ChAO) on new production and logistics technologies.	Boom of launched LNG and new "best practice" oil projects (Vostok Oil, etc.) relying on offshore logistics. *"LNG mania". Sabetta's "Big Bang" is the beginning of a new technological revolution in the Russian Arctic.* Start of development of the Baim ore zone (ChAO). Multiple growth in the volume of freight traffic along the Northern Sea Route. Formation of a new super organization for the modern development of the Arctic – Rosatom State Corporation, with innovative potential in mining, transport logistics and energy supply of new resource projects.

End of Table

	Period				
	1980–1992	1992–1998	1998–2008	2008–2014	2014–2021
		Establishing a new paradigm			
Arctic regions of the main events of the new technological revolution		Linking technological change in the Arctic with political, economic, and managerial reforms in Russia.	Rejuvenation of aged extractive industries and resource provinces in the Murmansk and Arkhangelsk oblasts, the Norilsk industrial district, and the Republic of Sakha (Yakutia) through the transition to the development of new natural sites in old places of economic activity (gas condensate, copper, palladium, ore gold, etc.).	Active financing of new projects by European and Asian foreign investors in YNAO, ChAO and Taymyr.	Active financing of new projects by European and Asian foreign investors in YNAO, ChAO and Taymyr.
The relationship between financial and productive capital		The distinction between financial managers and "red" production directors. Foreign and Russian financial capital helps new entrepreneurs to experiment with a new paradigm, "loosening" the inertia of previous development ("path dependence").	The distinction between financial and production capital, financial managers and production directors.	Start of connecting financial capital with production capital. Foreign financial capital in major Arctic projects.	Merging financial capital with production capital. Foreign financial capital in selected projects.
Backbone ICT infrastructure of the new paradigm	–	–	–	Active establishment	Creation of new ICT infrastructure for greenfield and brownfield resource projects. Digital Transformation of Arctic Corporations. Digital twins of real processes.
Source: own compilation.					

environmentally balanced nature management, which was associated with the formation of a new techno-economic paradigm in the Arctic[5]. Its features emerged here earlier and more clearly than in other Russian Arctic territories. Why did this happen?

The usual answers to this question consist of a reference to the phenomenon of development "from scratch", unencumbered by material assets and ingrained notions of the former industrial age, which worked well in that era, but are rather a brake on the new one. There was no such important factor in the rest of the Arctic autonomous okrugs and regions, which started active economic development decades earlier, but it alone cannot explain the phenomenon of NAO as a launching pad for the whole Russian Arctic.

Another circumstance often referred to is the luck of political independence, full-fledged subjectivity within the Russian Federation, which provided the new team of regional authorities with unprecedented powers in the management of regional development (for example, the right to use the regional quota of oil production to finance the socio-economic development of the region) and, even more important from the perspective of the new technological paradigm, full participation in all negotiations on new mining projects, which are about to be implemented. Other autonomous regions of the Arctic, which became independent subjects of the Russian Federation, also received unprecedented rights in the early 1990s, but did not become a testing ground for the new technological paradigm at that time.

Regional innovation-friendly environment: diversity, basic relationships, space

We are dealing with the complex phenomenon of the "positive selection" of the region as a pioneer of the new technological paradigm in the Russian Arctic, which cannot be explained by any single factor, even the most obviously favorable. It must be a system of interrelated factors and circumstances that led to the final result: the phenomenon of Silicon Valley described in detail (Saxenian, 1994) pushes us to this view: researchers note that its "spontaneous" appointment as the pioneering leader of American computerization and the fact that it outperformed the former recognized leader, Boston, Massachusetts, is the result not of a single factor, but of a systematically working group of factors that shaped the environment of experimentation promotion in which the conditions for mass adoption of computer innovations emerged.

In the case under consideration, we are not looking for a single factor, but for a group of factors-causes that were able to form an environment for encouraging experiments (both successful and unsuccessful, forgotten), and from this environment, success stories and best practices were "selected" and then replicated in the rest of the Arctic. The initial favorable circumstance for its formation was the exceptional diversity of natural assets – oil, oil-and-gas and oil-gas-condensate fields of the northern Timan-Pechora Basin[6].

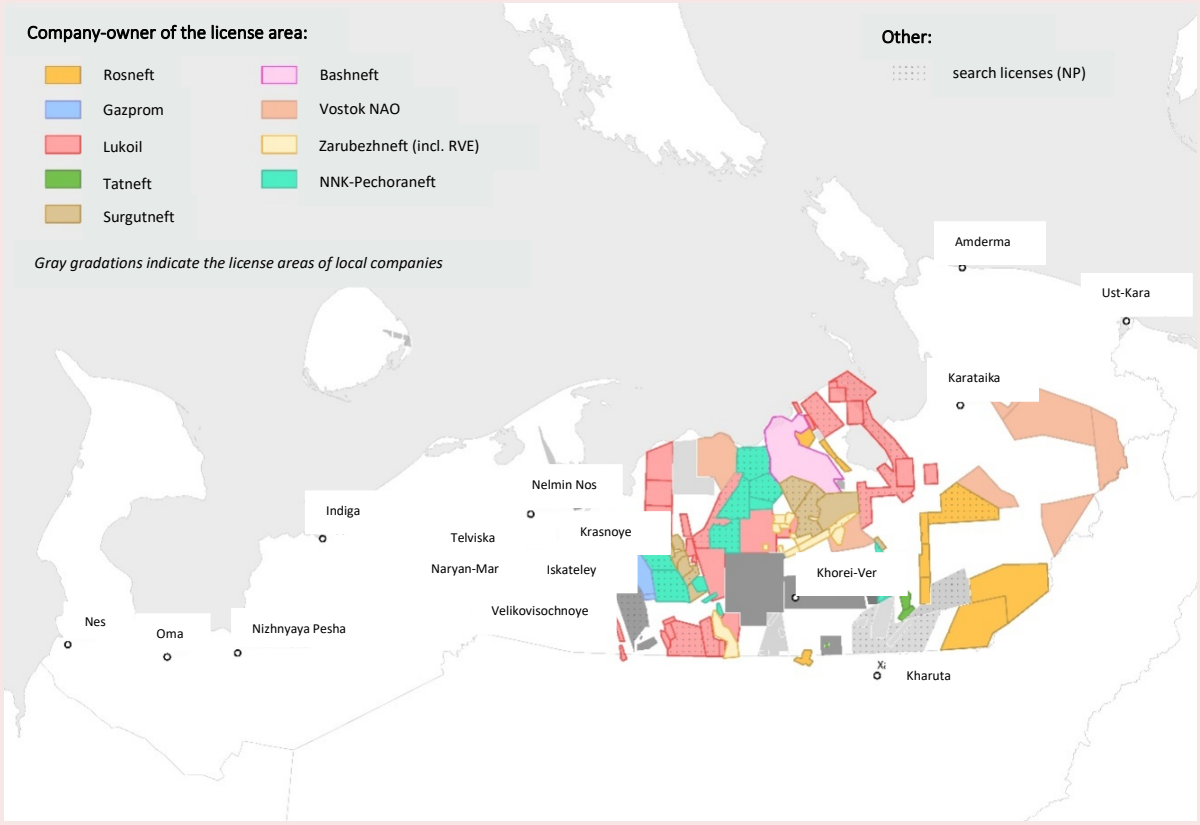
Radical differences of natural assets of the region from field to field (in sulfur content, viscosity, density, etc.) and high specificity of many of them have caused a "one-off" approach to each resource object and, accordingly, affected the large number of subsoil users in a relatively small mining area in comparison with other regions *(Fig. 1)*.

What was a curse in Soviet industrial times, which delayed the economic development of the autonomous district in the 1980s (for example, the Ardalin field was discovered back in the 1980s, and became a mining project in the mid-1990s): medium and small reserves with significant uniqueness of features of each natural object and the frequent

[5] *Nenets Autonomous Okrug: Territory of Paradoxes*. Moscow: Institute for Regional Consulting. 2022.

[6] Many researchers of Nenets Autonomous Okrug write about it, for example: "The characteristic feature of the northern part of the Timan-Pechora Basin is a large number of deposits with medium and small reserves" (Ilyumzhinov, 2003).

The environment of organizational diversity in NAO oil and gas sector



The layout of the license areas of key oil and gas production companies in Nenets Autonomous Okrug is a constructive condition for institutional and organizational diversity as a catalyst for the establishment of a new way of oil production.

Source: data from the Federal Agency for Subsoil Use for 2016.

Cartography: R.V. Goncharov, Candidate of Sciences (Geography).

presence of not homogeneous, but mixed natural assets, which the industrial late Soviet economy, set up to obtain the effect of saving on size, simply could not take (homogeneous in methane and oil were in vogue, without "impurities", the "right" fields of Yamal and the Khanty) – in the new economic era has become a condition for unique technological, organizational, logistical and institutional diversity, and this is the best environment for experimentation and innovation, for the formation of a new paradigm.

If the development of NAO had begun in Soviet times, the natural diversity of the fields would have been "drowned out" by a unified organizational scheme of development – one state company for the entire oil and gas territory. In the context of the new Russia, privatization of subsoil use rights and the initial autonomization of grassroots mining economic structures (under the pioneering development of NAO as a result of the arrival of new international companies and consortia of large foreign companies and Russian participants; in the old-developed Arctic territories, such as the Murmansk and Archangel oblasts – as a result of denationalization of old Soviet heads and trusts) this initial diversity of natural objects in their properties was, by contrast, emphasized at the expense of the emergence of different subsoil users.

The diversity of natural sites and their owners played the same role for the selection of NAO as a pilot site for a new technological paradigm as did dozens of Silicon Valley IT venture capital firms: in both cases, diversity was a condition for the formation of an environment of continuous, cascading innovation search and experimentation, in the roadless NAO in mining and especially logistics. The dual scheme of traditional "southern" pipeline and new sea transportation of hydrocarbons "according to the temporary scheme" (developed by the efforts of small subsoil users), which was timidly outlined already in the first years of NAO development, played an exceptional role for the subsequent approval of the principles of the new technological mode in the Russian Arctic.

In the innovation search of the first years of the economic development of NAO, the defeats meant no less, and even more than the best practices of the established projects, for the interrupted unsuccessful experiments consolidated the priority and significance of the victorious ones. The "spontaneous rightness" of the real situation was that the failures helped to select those projects and solutions that became temporary monopolists of luck. If the environment of mass experimental search was maintained for a long time, the resources of natural assets would not be enough for everyone, and destructive rather than creative competition with all the negative costs (destruction of competitors, corruption of state bodies to guarantee the appointment of winners, etc.) could take place.

Why this diversity of subsoil use structures and institutions was not quickly "extinguished" by the regional authorities, the Arkhangelsk Oblast, the federal center, the large monopolistic subsoil user? The regional authorities in the first years of the new development of NAO, led by the first governor Yu.V. Komarovskii, were aimed at unleashing the forces of territorial economic development and maximizing the social benefits of this process (Komarovskii, 2014). Unlike other Arctic regions, including autonomous okrugs, in NAO the radical transformation of the 1990s began in the conditions of pioneering development of unique natural oil assets, but without the presence of large corporate structures. That is, the local authorities had carte blanche to pursue an independent economic policy to a greater extent than the authorities of all other Arctic regions.

It was the regional government that secured the structural diversity important for innovation with a friendly environment, which was formed primarily by relations with the federal center, the Arkhangelsk Oblast, and the key subsoil users of the region. The common feature of all these relations was a constructive ambivalence, which implied the peaceful coexistence of elements of the old and the new (to go right through with the new would mean the destruction of the very possibility of experimentation).

Since the end of 1991, the autonomous okrug received considerable freedom in making economic decisions, such as the right to use the regional oil quota for socio-economic development. This freedom was constructively channeled by the regional authorities to encourage the development of natural resources in new forms and schemes that have been discovered and become possible.

Along with the general newfound independence compared to other autonomous districts of the Arctic, NAO had a number of important advantages in its relations with the federal center. Geographical proximity to the federal centers of decision-making was combined here with a total roadlessness, which meant, first, the ease of lobbying local decisions in the key centers of the country (the Presidential Administration, the Russian Government, the State Duma and the Federation Council), and second, the difficulties of bureaucratic control and guardianship of ongoing economic processes by federal ministries and agencies: it was more difficult to stop the experiments here. The "internal" position of NAO, as compared to the geopolitically sensitive ChAO, also favored the formation of effective working relations with the federal center.

Constructive ambivalence, which did not lead to conflicts (often in other cases they simply stopped all innovation experimentation), persisted for a long time in the relations of NAO as a new constituent entity of the Russian Federation with the "parent" Arkhangelsk Oblast. The newly-formed oil and gas constituent entity of the Russian Federation was economically stronger than the timber-producing region: "in 1993, as the first NAO Governor notes in his book of memoirs, more housing was built in the district than in all the districts of the Arkhangelsk Oblast combined" (Komarovskii, 2014). A different situation was observed in Chukotka Autonomous Okrug, which, being economically weaker than the "parent" Magadan Oblast, immediately and decisively broke with it, thereby losing the opportunity to support its economic initiatives in the early years of the reform.

NAO, on the one hand, had unprecedented new rights as compared to the Soviet past; on the other hand, it had an unfinished process of separation from the Arkhangelsk Oblast, which allowed receiving support from the Oblast for all of its initiatives. Undocumented independence, which is traditionally considered a brake on reform and innovation, in fact, in the first stage of the timid formation of the new paradigm can be a blessing, because it allows receiving support of the "parent structure" in the most difficult early years, forms the conditions for the subsequent unconflicted isolation. In the classical situation of the relationship between the parent structure and the innovation spin-off that has "hatched" from it, the conditions for its success are not only high independence in making innovation decisions, but also a conflict-free, peaceful relationship with the "parent", which is not easy to create, but they guarantee the successful formation of a new paradigm.

In the second half of the 1990s, PJSC Lukoil came to NAO, which in the 2000s became the largest actor in local subsoil use. In NAO, the local authorities met him cautiously and immediately began to strengthen the main structure of local subsoil use – the Nenets Oil Company. For this reason, but primarily because of the presence of other medium-sized subsoil users and significant political influence, Lukoil was unable to obtain all of the oil and gas assets here and thus turn Nenets Autonomous Okrug into its own monoprofile corporate territory.

It was the conditions of constructive duality – the largest, but not monopolistic – that ensured later, when Lukoil absorbed all small subsoil users and joint ventures (including the most important ones – Arkhangelskgeoldobycha (1997) and KomiTEK (1999)), its unexpected and constructive behavior for the okrug and the Arctic: it did not stop the innovation search, did not go for the "pipeline" proven logistics solution, as many experts thought[7], but consolidated the new offshore logistics of hydrocarbons export in the large-scale project of the Varandey Terminal.

The NAO territory was exceptionally favorable for the most radical innovations. The eastern zone of economic development lay outside the (western) territories of traditional settlement, including the indigenous peoples of the North and the Pomors. This means that the conflict over the land claims of the peoples of the North on historical ancestral territories was initially excluded, which significantly increased the investment attractiveness of natural assets for foreign investors.

The Timan-Pechora Basin extends to the south into the Komi Republic, and these are long-exploited and depleted natural assets; to the north, NAO, and these are young and fresh field assets. If the entire province were part of the Komi Republic, there would be no such innovation-friendly environment in its young north.

[7] "It seems to be more advantageous for Lukoil, which plans to produce oil on the continental part of the Timan-Pechora Basin, to transport oil to Murmansk in the usual way using the pipeline system rather than by small- and medium-tonnage tankers in the ice conditions of the Barents and Pechora seas...". (Toskunina, 2003, p. 242).

On the other hand, there was a division of the region into two resource bases: the northern part of the Timan-Pechora Basin extending from the south, from the Komi Republic, and the coastal Barents Sea part[8]. We can say that there was a natural zoning of the territory according to the degree of readiness for the new paradigm: the southern natural assets relied on traditional pipeline logistics, and the northern ones on the new maritime logistics. Unfortunately, in subsequent years this logically substantiated scheme was disrupted: "almost in parallel with each other, but in different directions, oil is transported through the Kharyaga – Varandey oil pipeline (Lukoil, from south to north through the Yuzhnoye Khylchuyu field) and from the Val Gamburtsev fields (Khasyreiskoye field) to the Baganskoye field (Rosneft, from north to south), *breaking the previously established structure of oil exports from the northern fields of the Okrug – through the Varandey Terminal, from the southern fields – through the structure of Transneft oil pipelines*[9].

NAO is the least populous region of Russia. But this means that there were very few potential resisters to the new things in place. And this again gave the local authorities carte blanche to encourage the boldest and most radical innovations in the 1990s.

"Spontaneous Venture" and corporate stages of the pioneering development of NAO

During the pioneering oil-industrial development of NAO it is important to distinguish two stages: the first, 1992–1999 – collective experimentation of small and medium firms and joint ventures, and the second, 2000–2008 – the corporate materialization of the previously found innovation solutions of Lukoil and other large companies. The forces and effects that worked in the first and second stages were completely different. First, the most important was the diversity effect of the work of small and medium subsoil users, and then the economy of the corporate scale of production.

For the first time in Russia, in 1992 a joint Russian-American enterprise Polar Lights (Arkhangelskgeologiya and Conoco corporation) was created for the production of oil within Ardalin project, which became the first in Russia example of using foreign drilling technology in the Arctic – only in winter, with specially frozen snow and ice platforms[10], so that the vegetation cover is not damaged and the tundra is not covered with "scars" from heavy machinery. A year and a half later, in August 1994, the pioneering Ardalin project of new oil development provided the first tons of oil. The project relied on the traditional pipeline export scheme: a special pipeline from the Ardalinskoye field to Kharyaga, 64 km long, was built for it. The Ardalin project became a place for preparing a new generation of specialists, trained to comply with environmental standards (Komarovskii, 2014) as an imperative of the new technological order, who subsequently worked at other Arctic enterprises (and the experience gained here was transferred further, to new Arctic projects).

At the end of 1995 an agreement was signed to develop the second major project of new oil industry development – Kharyaginskoye, which since January 1999 was implemented on the terms of production sharing agreements (PSA): NAO became a pioneer in the Russian Federation in introducing a co-financing scheme for field development with foreign partners[11]. Implementing the idea of a host region, in 1998 the authorities of the autonomous district created the Nenets Oil and Gas Company (NOC), which became a full participant in the PSA along with StatoilNorskHydro (Norway) and Total E&P Russie (France). In 2009 Zarubezhneft joined the project.

[8] *Nenets Autonomous Okrug. Modern State and Prospects of Development*. Saint Petersburg: State Polar Academy. 2005.

[9] *Nenets Autonomous Okrug: Territory of Paradoxes*. Moscow: Institute for Regional Consulting. 2022.

[10] See: http://www.oilru.com/nr/79/774/

[11] See: http://nnk.noilco.ru/projects/

The geological unity of the north and south of the Timan-Pechora Basin inevitably pushed the planners to continue the already established pipeline scheme to export NAO oil onshore and even offshore through the existing pipeline system to the south through the Komi Republic. It is not surprising that the first projects of oil-industrial development of the NAO (Ardalinsky and Kharyaginsky) were carried out exactly in this ideology. The oil from them was supplied by pipeline to Ukhta and then through the system of trunk pipelines to the west.

In order to start thinking in new categories, the existing alternative to the official traditional pipeline scheme in the form of a semi-legal maritime temporary oil export scheme was crucial, already in the early 1990s. Simultaneously with the pipeline, there was also a "capillary" modest and incomparable in terms of the volume of unloading ("experimental") experience of exporting oil from the Peschanoozerskoye field on Kolguev Island by tankers. It allowed thinking that offshore transportation in significantly larger volumes might be possible for the "mainland" projects of the northern Timan-Pechora Basin, located in NAO. Without the Kolguyev project, there would be no Varandey terminal or the entire maritime logistics of Arctic oil exports.

As small- and joint-venture owners came to the new maritime fields, the question of finding a suitable offshore terminal for exporting oil inevitably became more pronounced. In order to consolidate the efforts of the new owners and work out the optimal marine scheme and location for the terminal (primarily on the criterion of minimizing the length of pipeline transportation to it from the fields and the geographical convenience of the location), the Northern Gateway terminal project emerged. After several iterations, three options for terminal location were proposed: Indiga, Kolguev (Kaninsky), Varandey (Toskunina, 2003).

In competition with the Indiga and Kaninsky, the Varandey option had the advantage of minimal overland pipeline transportation of oil from the fields in the northern part of NAO (Toskunina, 2003) to the terminal along the Malozemelskaya and Timan tundra (it provided minimal impact on fauna and plant landscapes), that is, it was an option that relied on maritime transportation to a maximum extent.

The Varandey Terminal as the best location won out. However, it remained unclear who exactly would implement this option. The fact is that many experts doubted that Lukoil, which by that time had already become the leader of NAO oil production, would decide on new offshore logistics. Another thing was the experimental temporary oil loading near Varandey (already operated in 2000), which was easier to do, but it did not solve the problem of multi-million dollar oil loading, because such volumes required more powerful tankers, which could not approach the Varandey shallow water – so the terminal had to be stretched tens of kilometers from land, which dramatically increased the cost of the entire project, but ensured an order of magnitude of oil transshipment volumes.

But whether Lukoil would go for this "full-fledged" option was not obvious. In the Varandey area, the land passes almost imperceptibly into the sea, the depths are shallow, and the construction of a traditional oil port on land would require extremely costly dredging (there is a port, but it is not suitable for tankers). Lukoil decided to move the terminal 22 km offshore; the oil is transported by pipeline to the Fixed Offshore Ice-Resistant Offloading Terminal (FOIROT), and from the pier it is reloaded onto tankers. FOIROT was built in 2008.

The main success of the NAO was that, despite the radical changes in the nature of development in the first and second stages, the continuity of decisions was preserved, and this was due to the

conditions of structural diversity (incomplete monopoly of Lukoil), long-term key decisions made in the early 1990s, which could not be reversed – that is, the constructive dependence on the path. The transition from a small business to a major player has not broken the logic, it has preserved the continuity of the innovative maritime logistics solution, which Lukoil has made systematic: a deepwater Varandey terminal, specialized ice-class ships with partial icebreaker escort, a transshipment terminal from ice-class ships to ordinary cargo ships in the Kola Bay.

In terms of the sustainability of the regional system included in the experiment, there is the notion of excessive diversity, which can be devastating for the experiment itself, destructive for it and the new technological order associated with it. That is why the completion of the diversity phase in the early 2000s and the simultaneous promotion of Lukoil, which by then absorbed the bulk of the small subsoil users of the Autonomous Okrug, to the role of the superstructure of the economic development of the Autonomous Okrug was constructive. It was Lukoil that had sufficient investment resources to quickly implement a system-wide transition to revolutionary maritime logistics – a key element of the new technological order in the Russian Arctic. It provided continuity between the pioneering "temporary scheme" of offshore oil export by small and medium-sized firms in the first phase of pioneering development and the "monumental" solution in the form of the Varandey Terminal in the second phase of pioneering development of NAO.

For the new technological mode, all the details of the maritime logistics scheme, developed in the early years of new NAO projects, were of fundamental importance and had a huge potential for replication. If only a new system of marine logistics with all its elements were "invented" in NAO, it would already be a revolutionary contribution to the establishment of a new technological paradigm in the Russian Arctic.

Murmansk Oblast: Reasons for the brakes on the implementation of the new technological paradigm

Among the old industrial regions of the Arctic, the Murmansk Oblast is of particular interest in terms of the formation of a new technological paradigm, as it was the leading region of the Soviet industrial Arctic. The process of its turnaround from the former technological paradigm to a new one, from the large city-forming enterprises of the Soviet time, the extreme military closeness to the new projects of offshore development of NovaTEK and the realities of corporate development, was very long, and the obstacles arising on this way showed up in maximum relief.

Period of denationalization, privatization and investment crash (1992–2004)

The process of privatization of large state-owned mining and processing plants and their separation into independent economic cells and the process of "assembly" into branches – structural subdivisions of new Russian private holdings were accompanied by a long gap, during which the enterprises had illusions about the possibility of independent, autonomous survival in the new market conditions, and emerging large holdings had doubts about the attractiveness of Murmansk assets for acquisition, despite the global and all-Russian importance of most minerals on the Kola Peninsula (apatites, iron ores, copper-nickel ores, rare-earth metals), due to the significant burden of old industrial material assets and numerous social obligations. At a time when in other regions the new owners had already begun to implement their investment program, had been engaged in the superficial modernization of material assets and the transformation of basic business processes, in the single-industry towns of the Murmansk Oblast the structural changes at the main city-forming mining enterprises were still in progress.

There were opportunities to turn to a new paradigm in the traditional mining complex of the region – due to the arrival of foreign companies to the new development from scratch. During this period of "open door policy" for potential foreign partners, the Finnish company Outokumpu studied the prospects of developing the poor copper-nickel ores of the Lovozero deposit in the Pechengsky District; Australian BHP together with JSC Pana and the Kola Science Center of RAS conducted geological prospecting work for platinum and palladium in the Fedorovo Tundra and Pana massifs, while the Swedish concern Boliden obtained a license for exploration of molybdenum, silver and gold deposits in the Kolmozero-Voronya area in the Lovozero District; The Norwegian firm Elkem participated in supplementary exploration of chromite ores at the Bolshaya Varaka deposit in the Apatity region (Didyk, Ryabova, 2012); The Norwegian AO Khustkalk jointly with ZAO North-West Phosphorous Company and Kola Science Centre of RAS studied the possibility of organizing a joint venture on the coast of the Barents Sea to produce cement and alumina based on Khibiny nepheline and marble from the Askelberg deposit (Vinogradov, 2011). Many years of rosy hopes of effective cooperation during the development of oil and gas resources of the Barents Sea shelf at the edge of the century were associated with long-term plans of interaction between JSC Rosshelf and PJSC Gazprom (Murmansk) with such major multinational companies as Total, BP and STATOIL in the development of the Shtokman gas condensate field-giant with the formation of coastal logistics base on the Murmansk coast (Selin et al., 2008). Unfortunately, none of the above-mentioned areas has progressed beyond pre-project studies and prospecting and exploration work, which is unlike, for example, Chukotka Autonomous Okrug and the Magadan Oblast, where during this period joint ventures emerged at investment-attractive mining sites, which became the harbingers of features of the new technological paradigm in the basing regions.

Foreign capital, for specific reasons (primarily the conservatism of the local mining lobby, which is unfriendly to outsiders) did not become an agent of change in the first stage of transformations, which in the region was limited to institutional, but not technological, reforms. When a rare mining investor emerged in the region, they were pushed out with accusations that they were coming into an already established infrastructure, that is, opportunistically exploiting the Jack London effect (Huskey, 2017).

The paradoxical situation was that the Murmansk Oblast had at the beginning of the 21st century the most developed and advanced scientific and technological potential among all the Arctic regions of Russia and subarctic states, and the program of transition to the new technological paradigm was quite clearly outlined and substantiated in the works of the largest at the time Arctic scientific institution – the Kola Science Center of RAS (Kalinnikov, Vinogradov, 2005; Kalinnikov, Vinogradov, 2012). An in-depth analysis of the reasons for the stalling of innovation showed that the key drivers of progressive evolution were inside, not outside, the local production system at the time. In an attempt to find these endogenous causes, we analyzed the structure of the research work of the basic regional economic division of the Murmansk Oblast – the Institute of Economic Problems of the Kola Science Center of RAS[12].

Already in the topics of five-year research works (R&D) in the early 1990s[13], the priority of the development of offshore oil and gas fields in the West Arctic regions is noticeable, which goes beyond only the Shtokman project to a systematic

[12] We use the data from the monograph: *The Arctic in the Research of the Luzin Institute for Economic Studies of the KSC of RAS: Thirty Years of Scientific Search*. (2017). Ryabova L.A., Bashmakova E.P. (Eds.). Apatity: Izd. KSC RAS.

[13] For example, the topic "Comprehensive Assessment and Determination of Resource Development Strategy for the European Arctic".

awareness of the potential role of the Murmansk Oblast in this new coastal and offshore development of Western Arctic resources. Another powerful theme, absolutely consonant with the imperative of the new technological paradigm, was the regional industrial and innovation policy in the North. It was set in the studies of the Institute of Economic Problems already in the early 2000s (in a narrower format – for the mining complex – even in the theme of research 1991–1995). At the same time, the topic of creating the Apatity Technopark was put forward, but was also not implemented in practice. Back in the 1990s, regional experts foresaw quite accurately what kinds of activities would be associated with the formation of a new technological paradigm. But then the question arises: what is the reason for the stalling of its implementation in the Murmansk Oblast?

The first window of opportunity associated with unprecedented decentralization and new rights of the regions, the Murmansk Oblast could not use, because there were no free natural assets, small in size and therefore attractive to investment-poor small and medium firms, which in other regions carried out on these objects the first experiments with elements of the new paradigm. Such enterprises appeared in the region, but only in the field of geological exploration, and never reached the stage of mining operations due to the resistance of the local mining lobby, which gained unprecedented rights during this period due to privatization and corporatization. Later, the strength of resistance to change increased in direct proportion to the degree of monopolization of the national market by Murmansk enterprises, and it was large for each enterprise in its market niche.

Local experts did not see these small firms as real agents of change because they were traditionally used to the dominance of large military and civilian structures in the field. So, on the part of regional economic science, which in general correctly assesses the main vector of movement toward a new paradigm, has not matured an understanding of the specific actors who could stir up the local atmosphere and become the first drivers of change.

Thus, the main trouble of the Murmansk Oblast during this period was not the protracted privatization of the main city-forming enterprises, but the implicit, yet powerful containment of the transformation process. The main problem was that a new mass layer of small and medium-sized subsoil users has not emerged. It is this non-traditional for the regional economy group of economic entities could enter the production of new types of minerals or old, but with new technologies on new license areas. However, the whole system of local subsoil use resisted their mass arrival.

According to local experts, the large enterprises of the Murmansk Oblast themselves, "holding a monopolistic position in the market, are not always interested in intensive innovation development and often consider innovation activities as optional, which distracts from achieving the main objectives, including the maximum profit" (Tsukerman, Goryachevskaya, 2020). As local monopolists, they limited the entry of new actors into the region and the transfer of old and new license areas of promising fields to them, which was the main reason for the temporary stalling and super-slow maturation of the new paradigm elements in the region's economy during this period.

The period of surface modernization (restructuring) of mining enterprises in the region (2004–2012)

The ranking of the innovation climate of the "Expert-RA" agency from 2000 to 2014 records the deterioration of the Murmansk Oblast, which moved from 35th place to 55th in the circle of all Russian regions. At the same time, another old industrial territory of the Russian Arctic, the Arkhangelsk Oblast, improved its position (primarily due to the new federal university NARFU, established during this period), rising from 46th

to 39th place[14] (Mechanism of Coordination..., 2016, p. 54). A leading expert on the development of the Murmansk Oblast, Professor V.S. Selin writes about "walking around in a circle and the reproduction of previous delusions" (Mechanism of Coordination..., 2016, p. 27) as a phenomenon of old industrial territories, which can be fully attributed to this period of development of the Murmansk Oblast.

The structure-forming enterprises of the Murmansk Oblast: Kola Mining and Metallurgical Company, OJSC Olkon, OJSC Kovdorsky GOK, OJSC Apatit – became part of federal holdings and became dependent on their investment programs, i.e. were mostly limited to "light" unburdening modernization in the form of purchasing imported equipment, transferring many types of work to outsourcing, reduction of employees and partial transition to the shift work organization method. There was no strategic restructuring of the Murmansk enterprises during this period.

The main bet was made on the renewal of technology and the reduction of employment. That is, there was no talk about the transition to a new technological way of life with the necessary revolutionary innovations, rather than operational budgeting in the interests of maximizing profits and cutting investment and social programs. This period worked very poorly to solve the problems of establishing a new technological paradigm in the Murmansk Oblast, although it was then that the issue of "active industrial policy aimed at the establishment and development of new technological paradigms in the European North of Russia" was first declared as the topic of the Institute of Economic Problems in 2008–2010 (research supervisor V.S. Selin). It was blocked together with the developments on innovation industrial policy, innovation industrialization, modernization, regional science and technology and innovation complex, which were carried out at the Institute at that time. There were works on the strategy of marine activities in the Russian Arctic, on the Western Arctic shelf areas, and an assessment of the regional effects of the Shtokman project (for which there were hopes) and the LNG plant in Vidyaevo. Gradually the understanding has been formed, what exactly the new technological paradigm in the Murmansk Oblast will be connected with: of course, with an active innovation industrial policy, new types of marine activities, which will "refresh" and give the local economy a new development tone, as well as with the formation in the region of the national center for providing high-tech industries of Russian industry with rare metal and rare earth components of strategic importance (Selin et al., 2006; etc.).

The period of deep modernization and the region's entry into a new technological paradigm (2012 – present)

Within this period, in terms of the radicality of transformations, it is important to distinguish between the first stage of rejuvenation of the existing decades-long development path, which was carried out by new actors who came to the region (they are the ones who started this process) and local actors; and the stage of creating a radical new path associated with the arrival of NovaTEK and its project of the Large-Scale Marine Facilities Construction Center (LSMFCC) in the Murmansk Oblast.

In 2005, the North-Western Phosphorous Company (NWPC), a subsidiary of Acron, was established in the region. Initially, its activities had little effect on the interests of the "grandees" of the mining business operating in the region: for the first few years it bought apatite concentrate from Apatit and was totally dependent on its monopolistic pricing. But that all changed when LSMFCC launched its own production of apatite concentrate at the resources of the Oleniy Ruchey deposit in 2012.

[14] Ratings of investment attractiveness of Russian regions.

The significance of this project was absolutely revolutionary for the very conservative environment of the region's mining industry. From that moment the real, long-delayed, deep organizational and technological changes at the region's mining enterprises began. The strength of new projects in the old industrial region (and by the "volume" of their impact they differ from new projects in the pioneering development area, where the process is "from scratch") was that even without significant economic effects on the regional economy in the form of new employment and budget revenue flow they have a profound mental impact on the production atmosphere, on the atmosphere of economic management in the region.

The success of the external competitor broke the monopolistic immobility of the environment and stimulated the introduction of technological, organizational, and personnel innovations at the Murmansk mining enterprises (transition from purchase of new equipment to reconstruction of old factories and implementation of new business processes and their total digitization, attraction of drive-in-drive-out workers, outsourcing of non-core activities, development of new fields within the framework of long-standing license areas, etc.). The stimulus for the regional authorities to encourage these processes was the final closure of the Shtokman project for an indefinite period (until the 2030s).

An indirect criterion of the depth of modernization of production processes is the fact that for the first time the issue of innovation modernization began to merge with the issue of development of single-industry towns in the Institute of Economic Problems. For the first time, an agreement was concluded between the region and PhosAgro to support innovation activities for ten years (2016–2026). The studies outlined the complex phenomenon of regional innovation system, including in the context of interaction between mining corporations and the region in the formation of innovation policy (in general, the topic of corporations in the aspect of innovation transformation has received more attention), the concept of intelligent field was formulated, the topic of small businesses as an agent of innovation transformation was raised, etc. The phenomenon of the Murmansk Oblast as an old industrial territory with its own typical blocks of innovation development (primarily the phenomenon of path dependence) was comprehended. There has been a transition from the general absolutely correct formulations of the directions of new development, made by regional experts back in the 1990s, to an understanding of the main actors, institutions and systems, in which the transition of the region's economy to the new technological mode should be carried out.

In the 2020s, NovaTEK commissioned the LNG Construction Center (LNGCC) in the Kola Bay of the Barents Sea (Belokamenka settlement). In terms of "discovering" a new technological path of the region's development, we can call this project an analogue of Shtokman. It has become a real fact of forming a new technological paradigm: the construction of a gravity platform plant for LNG production integrates the region into that new production, which is already developing in the first Arctic projects in Yamal-Nenets Autonomous Okrug.

There is a paradox in the recent economic history of the Murmansk Oblast that favorable factors (the cross-border position potentially promising spillover of knowledge, competences and technologies, a powerful warm-water port, the richest mineral and raw material base of the Khibins, the relative proximity to the federal capitals) started working to slow down rather than to speed up radical technological modernization on the principles of the new paradigm: proximity to European Union countries and federal capitals contributed to the outflow of young enterprising personnel (a total of hundreds of thousands of

people left the Murmansk Oblast during the first two decades of reforms); hopes for large-scale foreign investment from neighboring countries have also failed; the region's rich mineral resource base has been used to generate profits at the headquarters of federal holdings, but not for an active and innovative investment policy in the mining and industrial complex of the region itself. On the contrary, local city-forming enterprises, wanting to maintain a monopoly position in their markets, prevented the emergence of new external players.

What local experts call the vice of "weak diversification" and "the policy of continuing narrow specialization" (Didyk, Ryabova, 2012, p. 64) is actually the phenomenon of "path dependence" and "development blockages" described in the world literature (Zamyatina, Pilyasov, 2015), which in the specific case of the Murmansk Oblast for two decades has stalled its progress toward the new technological paradigm, which has numerous favorable conditions to take place relatively quickly here.

Comparison of the formation of a new paradigm in NAO and the Murmansk Oblast

The main events in NAO took place in 1992–2008, after which the development on a new path entered a calm (stable) direction. On the other hand, in the Murmansk Oblast the main events began to unfold with increasing intensity already in the 2010s, when the arrival of new actors, including those in completely new economic activities for the region, finally broke the inertia of dependence on the past path and put the region on the path of the formation of a new technological paradigm.

In NAO, where development was carried out "in a new way", without the creation of a stationary network of single-industry towns, they could not become independent participants in the process of technological modernization, and the capital Naryan-Mar played above all the role of an air base for transferring rotational workers to corporate vehicles for delivery to the field sites. In the Murmansk Oblast, single-industry towns characterized the previously urban nature of the resource industries, and therefore a radical modernization of the industries was not possible without a radical renovation of the urban economy.

Comparing the Murmansk Oblast and Nenets Autonomous Okrug in terms of their development path over the past three decades raises the question of how the type of natural asset and the forms of its occurrence affect the pace of institutional and organizational change. All other things being equal, for the purposes of radical reform it is better to have small and medium-sized deposits, relatively easy to take, even in adverse transport and geographical conditions, which can be (easier) to work out by small and medium-sized business structures.

In this case, the small size, relatively high content of the useful component, its uniqueness by any parameter is more important than the convenience of logistics. The realities of the emergence of new projects in the Russian Arctic in the early years of reforms confirm that small businesses were able to find original and innovation logistics solutions, but they were not able to override the laws of nature and change the properties of existing natural assets.

The NAO's commitment to radical reforms in the 1990s was partly determined by the fact that small and medium hydrocarbon fields were organically adapted to the start of development by small and medium-sized subsoil use structures. On the other hand, large ("block") natural assets of the exploited ore deposits of the Kola Peninsula, on the contrary, made it difficult for small business structures to divide and split them. Thus, and from the properties of natural assets, there were factors inhibiting technological modernization in the Murmansk Oblast.

The type of natural resource also matters. Due to the fact that oil generates unprecedented rent compared to other natural resources (Etkind, 2020), NAO hydrocarbon deposits in the early years of

reforms "spilled" partial income into the region as well, which gave regional authorities the power of politically independent decisions – and if they were set up for an active industrial policy, this became a major positive factor for dynamic transformations. On the other hand, the mineral resources of the Murmansk Oblast could not generate a rent of comparable size. The degree of alienation of the region from the natural resources in its subsoil and the income generated from them (precisely because of its comparatively smaller size) was higher than in the Autonomous Okrug, where the comparative size of the rent is larger and the number of inhabitants is many times smaller.

The dependence of the authorities of the Murmansk Oblast on the federal decisions and support, its lack of independence in comparison with NAO authorities was much higher. For a long time it had neither financial resources, nor administrative weight to conduct an independent industrial policy.

In the process of technological modernization, the space of both regions was divided into a part that remained relatively conservative and retained the economic features of the former technological paradigm, and a significantly more dynamic part, which entered the process of technological reform, was due to many reasons more ready for it. Naturally, during the process of technological modernization, in both regions there was an internal production and technological zoning of the territory according to the degree of its readiness for the new paradigm.

In NAO, this is a rift into the coastal part of the Barents Sea, which fields were naturally exposed to the new maritime logistics, and the "southern" part, which remained faithful to the former pipeline logistics. In the Murmansk Oblast, this is a hinterland of old mining development consisting of numerous single-industry towns (Olenegorsk, Monchegorsk, Apatity, Kirovsk, Kandalaksha, Kovdor, Zapolyarny) and the urban-type settlement Revda, on the one hand, – here for a long time there was only superficial technological modernization, and then updating the long-existing development path; on the other hand, the east of the Kola Peninsula and the Kola Bay, where the regional capital Murmansk and numerous closed towns (Severomorsk, Alexandrovsk, Zaozyorsk, Vidyaevo, Ostrovnoy) are located, where in the 2010s a new development path was being created: projects emerged in new types of activities (e.g., LSMFCC) or in the development of new mining license areas.

Obviously, the institutions and tools of industrial policy of the regional government, aimed at the formation of a new technological paradigm, must be adapted to each production and technological paradigm: for example, in the north of the Murmansk Oblast, it is critical to bring in new companies, while in the center it is critical to create industrial parks and strengthen the triple helix of science-business-government relations for the mass implementation of new technologies and the search for new opportunities in line with existing development paths.

Discussion and conclusions

The realities of the past 30 years in the socio-economic development of the regions of the Russian Arctic indicate a significant diversity, while the presence of common vectors, in the trajectories of their movement to a new technological paradigm based on information and communication technologies, remote control, artificial intelligence technologies and digitized business processes. The relative equality of development of the Russian Arctic territories achieved by the end of the Soviet industrial period was replaced by strong interregional contrasts when radical economic reforms began in the 1990s and deep institutional, technological, and organizational transformations were initiated.

These contrasts are natural for the stage of formation of a new technological paradigm and, on the one hand, are determined by different starting conditions of the regions included in the transformation; on the other hand, are associated with different speed, intensity of the transformation process, differences in the years of rapid deployment of mining projects, carried out in the ideology of the already new economic era. They determine the rapid displacement from the pedestal of the leaders of the former industrial era and the advancement of entirely new Arctic regions into the role of technological leaders.

The "code" for the formation of a new technological paradigm, common to all regions, is as follows.

1. Pilot projects play an enormous role in breaking the inertia of the former path in old industrial areas or shaping a new path in pioneering areas. As a rule, they do not yet have the radical innovation to have zonal (for the entire Arctic) replicability potential, they carry the features of the new and the old (for example, new "platform", robotic mining, but old logistics). These new projects are very rarely implemented by the economic grunts of the former industrial era. As a rule, these are structures with varying degrees of organizational novelty: newly formed corporations, "daughters" (spin-offs or spin-outs) of old enterprises and production associations, joint ventures with a foreign participant, a layer of small and medium-sized businesses.

2. The pilot project launches the process of deep technological modernization not only by the fact of its appearance, but also by the formation of a new economic atmosphere in the region of its base, the "dissolution" of previous intellectual perceptions (and that is really already possible?). And it is no coincidence that the projects that follow have significantly more innovation and boldness, and thus the potential for replicability for the entire Arctic.

3. The process of technological modernization acquires genuine sustainability in a friendly environment, which is formed by efforts in the field of new industrial policy of regional authorities (in the old industrial regions – jointly with the authorities of single-industry towns). Success in the new industrial policy is determined not only (not so much) by the size of the financial resources in the hands of the local government, but by the formation of new relationships with the federal government, key companies in the region and local manufacturing businesses. These relations necessarily bear the stamp of constructive ambivalence, that is, a combination of tradition and innovation. Excessive traditionalism threatens conservatism, while excessive innovation can destroy the germs of a new paradigm in the region "in the bud".

4. Regional authorities are required to be both persistent and patient in the difficult task of building an environment favorable to innovation. Without encouraging innovation and experimentation in the extraction, logistics, and marketing of natural resources, one cannot hope to form the foundations of a new technological paradigm. The fact is that one project out of a dozen is selected and "assigned" to flagships. But without a wide field of experiments, the final winner cannot be identified, officially recognized and administratively appointed as a demonstration site for the new technological paradigm.

5. A flagship project with significant potential for replication of its individual successful elements throughout the Arctic is usually implemented by a federally recognized corporate structure that materializes in practice the innovative ideas and approaches of small structures developed in the previous stages of development.

At the current level of knowledge about the ways of the Arctic regions' entry into the new (information) technological paradigm, the following questions seem insufficiently elaborated:

– which specific material and socio-cultural (institutional) factors ensure the transition from individual atomic projects of the new technological era to its takeover of the entire region, and how these factors differ from one Arctic region to another;

– whether it is possible to significantly influence the speed of deployment of the new technological paradigm (turn on the "turbo" button) in the Arctic regions and what measures/structures/institutions of the regional and federal authorities;

– if we consider the development of the Arctic regions from the standpoint of paradigms, is there an opportunity to reduce the length of the formation and deployment of a new (information) technological paradigm and move more quickly to the next one, based on biotechnology, life sciences, materials with predetermined properties (3D printing, etc.)?

The most important task for scientific study is to consider the optimal forms of state influence on the process of formation of a new technological paradigm in the Russian Arctic by instruments and institutions of active industrial policy at the federal, regional and municipal levels in the interests of maximizing benefits and minimizing social costs.

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