

The growth and shrinkage of coal cities in the paradigm of technological transition: cases of Russia and China (within the framework of the project "Dynamic urbanistics: a comparative analysis of the cities with rapid population changes in Russia and China")

The global energy transition – driven by the need for decarbonization, the depletion of easily accessible fossil fuel resources, and the shift of dominant technological paradigms – presents unprecedented challenges to resource-dependent regions. For over a century, the coal industry served as the foundation of industrialization and energy security for many nations. Today, it finds itself at the epicenter of a structural crisis. Cities whose existence and prosperity have been historically tied to coal mining now face the imperative of radical transformation, ranging from the search for new growth poles to contraction and depopulation.

Russia and China present a particularly compelling focus for comparative research. Both nations possess vast coal-mining regions with unique histories of development, distinctive urban environments, and specific socio-economic characteristics. At the same time, their institutional frameworks for managing resource territories, their adaptation strategies to changing conditions, and the role of the state in these processes exhibit both similarities and profound differences, stemming from divergent political and economic systems.

The objective of this study is to identify common patterns and specific trajectories in the development of coal towns in Russia and China within the context of global technological transition, and to analyze the factors that determine the success or failure of these territories' adaptation to new economic and technological realities.

The empirical focus is on the cities of Kuzbass in Russia and the city of Fuxin in Liaoning Province, China. This choice is justified by their representativeness: both regions hold an unofficial but persistent status as the "coal heart" of their respective countries, underscoring their pivotal role in the formation of the industrial complex during the industrialization era. Kuzbass represents an integrated coal-industrial agglomeration where mines, processing plants, metallurgical and chemical production facilities are distributed across multiple cities, forming a unified production chain that remains the backbone of the regional economy. Fuxin serves as a classic example of a Chinese coal industrial city that has undergone a transition from rapid industrialization to a resource crisis due to the physical depletion of coal reserves. Today, both regions are experiencing significant population outflows, particularly among the youth.

The research methodology combines several approaches: analysis of demographic dynamics based on census data and current statistics (for Kuzbass, data from the All-Union and All-Russian censuses of 1897–2020; for Fuxin, statistical data to be gathered in the next phase of the work); analysis of historical sources; comparative-historical method; and elements of qualitative analysis, including fieldwork materials.

The theoretical framework is built upon two concepts integrated within the emerging research direction of "dynamic urbanism," which studies rapid changes in the nature of urban development in connection with the global shift of technological paradigms, and in particular, the transition to post-industrial development conditions.

The first is the concept of technological transitions (Kondratiev, Perez). This concept examines deep-seated transformations of socio-technical systems, involving shifts in dominant technologies, institutions, practices, and cultural meanings. Coal towns are considered part of the broader socio-technical system of energy supply that formed within the third and fourth technological paradigms. The global technological shift towards low-carbon energy creates pressure on this system, demanding its reconfiguration. The research focuses on how this global process is refracted at the local level – in specific cities whose economies and social lives have been built around coal for decades.

The second concept is the frontier model. The frontier is understood as a zone of rapid natural resource development, generating explosive population and urban growth, forging new cultural attitudes and ways of life, but ultimately oriented not towards permanent settlement, but towards the most efficient extraction of resources demanded by the dominant technological paradigm. The

classic frontier description posits that once the resource is exhausted or its significance for the new technological paradigm declines, the population departs as swiftly as it arrived, as the entire economy was built on raw material exports. However, as Arctic researcher Lee Huskey has shown, if a sufficiently large population capable of generating local demand emerges during the development phase, "life goes on" even after the resource is exhausted – a phenomenon termed the "Jack London effect." Within the framework of dynamic urbanism, this model helps explain why some resource-dependent cities retain viability after the exhaustion of their primary economic function while others decline.

The combination of these concepts provides an analytical framework where coal towns are seen as settlements that have passed through one or more frontier waves and now find themselves in a situation demanding a technological transition. The central research question becomes the problem of desynchronization: to what extent does the dynamic of institutional and technological change in coal towns align with global trends, and at what points does a gap emerge? How does this misalignment affect the prospects of these cities – does it lead to the conservation of outdated structures (path dependency), or, conversely, does it open specific windows of opportunity for development?

Analysis of Kuzbass's historical dynamics reveals several successive frontier waves, each leaving its imprint on the region's demographic structure, economy, and cultural identity.

The first wave was linked to the 19th-century gold frontier. The first half of the 19th century saw a "gold rush" in Siberia. The city of Mariinsk became a staging point for gold prospectors, and the construction of the Trans-Siberian Railway in 1895 gave further impetus to its development. However, by the early 1920s, gold mining in Western and Eastern Siberia declined, and this frontier came to an end.

The second, crucial wave was associated with the development of coal resources and the creation of a modern industrial complex – this was not just a resource frontier, but a technological frontier. A unique historical experiment played a decisive role here: the Autonomous Industrial Colony "Kuzbass" (AIC), which existed from 1921 to 1927. In the depths of the economic crisis following the Civil War and foreign intervention, the Soviet government sought help from the international workers' movement. The AIC Kuzbass was a unique socio-economic experiment: the colony was exempt from all taxes and granted the right to duty-free import of equipment and materials.

The third wave of growth occurred during the period of forced industrialization in the 1930s and the war years of the 1940s. By the early 1940s, 11 new cities had emerged in Kuzbass. During the Great Patriotic War, the region became a hub for evacuated enterprises: equipment from 82 plants was fully or partially relocated, and 33 new production facilities were established. The post-war period cemented Kuzbass's role as one of the USSR's principal industrial centers.

Demographic data vividly illustrate these waves. In 1926, the population of the largest cities was measured in thousands (Kemerovo – 21.7 thousand, Novokuznetsk – 4 thousand). By 1939, it was counted in hundreds of thousands (Novokuznetsk – 169 thousand, Kemerovo – 133 thousand, Prokopyevsk – 107 thousand). The population peak for most cities occurred in the 1980s: Novokuznetsk reached 600 thousand, Kemerovo – 520 thousand, Prokopyevsk – 274 thousand.

The fourth phase is characterized by post-Soviet contraction. Starting in 1989, the trend reversed to steady decline: between 1989 and 2002, the average population decrease across Kuzbass cities was 11.4%, followed by another 4.4% between 2002 and 2020. The most dramatic shrinkage is seen in single-industry mining centers: Leninsk-Kuznetsky lost over 40% of its population from its peak, and Anzhero-Sudzhensk approximately 40%. Notably, even Mariinsk, the city of the first "gold" frontier wave, has maintained a stable population of around 40 thousand since 1959, which may be attributed to inertia and its incorporation into the subsequent industrial wave.

It is crucial to emphasize that the contraction in Kuzbass is occurring despite the presence of significant remaining coal reserves. This fundamentally distinguishes this case from one of physical resource depletion. The causes of shrinkage are complex: declining profitability of mining under new economic conditions, loss of traditional markets (including the cessation of supplies to

Europe), environmental constraints, rising production costs, overburdened transport infrastructure, and institutional inertia hindering adaptation to the demands of the global energy transition.

A partial buffer is provided by the "Jack London effect" : the largest cities (Kemerovo, Novokuznetsk) retain population due to accumulated inertia and relative diversification, while smaller, single-industry mining towns experience the most intense population loss.

In contrast to Kuzbass, where contraction happens alongside remaining resources, Fuxin exemplifies the classic "resource curse" in its final phase. Its coal industry was wound down due to the physical exhaustion of reserves. The fundamental difference between the two cases, therefore, lies in the nature of the crisis: for Fuxin, it is resource depletion necessitating post-resource transformation; for Kuzbass, it is the loss of economic efficiency despite continuing extractive potential.

The state adaptation strategy in Fuxin has focused on active restructuring: large-scale reclamation of disturbed lands (including the creation of Asia's largest park on the site of an open-pit coal mine), the establishment of new industrial zones, attraction of alternative industries, and worker retraining programs. Field research conducted in Fuxin has made it possible to document several qualitative characteristics of this post-coal transformation. However, according to available expert assessments, despite active state policy, the replacement of lost jobs remains incomplete, and the city continues to face depopulation challenges. A more detailed analysis of Fuxin's demographic dynamics and economic structure is planned for the next phase of the research (spring-summer 2026).

The conducted analysis allows for several preliminary conclusions. Both cases demonstrate that coal towns, which emerged as anchor points of previous technological paradigms, confront the need for deep transformation amidst shifting technological paradigms. The nature of the crisis – resource depletion versus loss of economic efficiency – shapes the available adaptation strategies and their potential effectiveness.

Fuxin's experience shows that even with active state-led diversification and reclamation policies, including flagship projects like creating an eco-park on a former coal mine site, fully overcoming the consequences of a resource crisis takes considerable time and does not guarantee an end to population outflow. Kuzbass, for its part, illustrates a different trajectory: the persistence of a resource base alongside its declining economic efficiency generates an inertial scenario where the largest centers maintain relative stability due to accumulated potential, while smaller single-industry towns degrade most intensively.

Further research will focus on:

- An in-depth analysis of institutional adaptation mechanisms in both regions, including a comparative study of diversification programs and their outcomes.
- Developing the theoretical framework of dynamic urbanism for resource territories undergoing a shift in technological paradigms.

Understanding these mechanisms is critically important for formulating effective policies for coal territories, which today find themselves on the front lines of structural change.