



UNIVERSITAT
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DE VALÈNCIA

ADE
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Administración
y Dirección de
Empresas /UPV

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**“Efectos del contexto histórico en el desarrollo de los
sistemas de innovación en Europa del Este”**

**“Effects of the Historical Context on the Development of
Innovation Systems in Eastern Europe”**

Trabajo de Final de Grado

**Alumno: Ricard Peiró Martí
Tutor: Honorat Roig Tierno**

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1. Introduction

1.1 Work Scope and Objectives

This dissertation aims to explain the development of Russia's National Innovation System (which will be referred to as NIS from now on) in parallel with its history from 1875 to the present day. The work will follow the informal and formal NIS development in Russia in the last 150 years, from Tsarist Imperial Russia to the USSR to the Russian Federation. The main focus of the work will be on the NIS located within the internationally accepted borders of the time.

Other countries will be used as benchmarks to measure development and the impact of historical events on their NISs. Similarity in size and influence on global politics has been considered when choosing the countries. The USA is the obvious choice because of historical development and antagonism throughout the 20th century. When necessary, other countries will also be used for comparisons, and in these cases, the reason for choosing will be stated.

The objectives are: First, to introduce the context of the topic, studying the economic and sociopolitical development of Eastern Europe. Second, to study the concept of a NIS and how it has evolved. The final objective is to use the two previous objectives combined to explore how the NIS has evolved in Eastern Europe in the last 150 years and the reasons that have influenced its development.

1.2 Reasons for Interest in The Topic

The interest in this study is dual; both the theme and the subject of the inquiry pose an exciting challenge. Innovation has become a central theme in countries' economic development. Since the 1990s, it has become critical to policy making and the competitiveness of countries on the global stage. The study of NISs has become an essential aspect of measuring innovation performance used by countries and global institutions alike (Chaminade, Lundvall & Haneef, 2018).

Modelling innovation as a system allows for an investigation over time and permits the study of how events of history condition the NIS and its development. It also proves invaluable in comparing countries and investigating the importance of policy-making on innovation. At the same time, the system model acknowledges the individuality of each nation and how the same policy may have a positive effect on one system and a devastating impact on another.

The subject of the study is Russia, which, as one of the leading players in global politics and the largest country in the world, poses a unique NIS to study. Furthermore, Russia has been intermittently at war for the last ten years with Ukraine, which has had profound implications both domestically and geopolitically. Russia also poses a fascinating subject because of its rich history in the previous 150 years, when political turmoil and autocracy have been the only constants. The country has seen different political systems and ideologies in government, each with its policymaking affecting the NIS. It has been involved in all significant global conflicts since the Napoleonic wars.

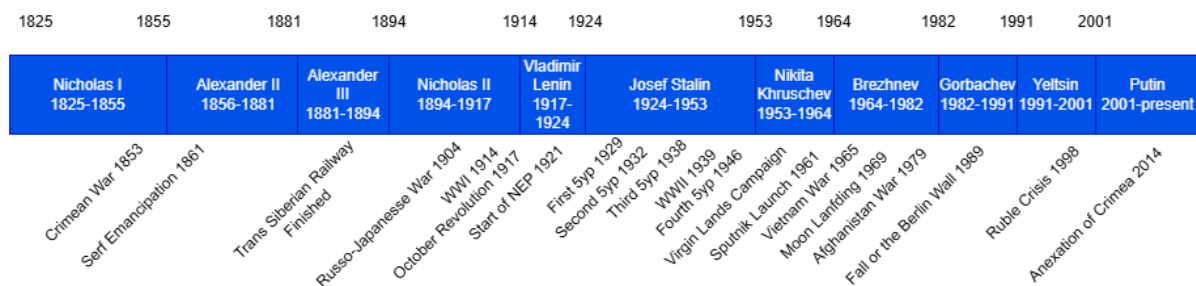
2. Context

In this section, a historical context will be introduced, exploring the government changes and major historical events, both domestic and global, in the period spanning from 1875 to the present. For further reference, the annex on Russian Geography can be consulted.

2.1 Russian History

This section will attempt to present the main events in Russian history, which will be analysed in section 4. The period that concerns this work will be from 1875 to the present, covering the last 150 years of Russian history. However, a short context will be added before 1875 to give an idea of the state of Russia at the start of the study. Legacy is an essential aspect of the Russian NIS that is delicate to change and set in its ways.

Figure 1. *Timeline of the studied period.*



2.2.1 Russia Pre-1875

This section is concerned with the build-up to the period of study. The sources used to support this section are Blinnikov (2011), Madariaga (1996) and Seabag-Montefiore (2015).

2.2.1.1 Nicholas I (1825-1855)

Nicholas I was a conservative monarch who tried to establish his position as an autocrat despite the growing social unrest. During his reign, his main aims were to centralise power and homogenise the empire, abolishing local laws and customs. He also inaugurated the first Russian railways, first for his private use and later for public use. The rest of the Caucasus was annexed after a victory in another **Russo-Persian War 1826-1828**. This region stayed part of Russia until the fall of the Soviet Union in 1991. His primary military defeat in the **Crimean War (1853-1856)** marked his reign's end, exposing Russia's military weakness.

2.2.1.2 Alexander II (1856-1881)

The sources used to develop this point where Pomeranz (2019) and Seabag-Montefiore (2015).

Alexander II was responsible for all the liberal reforms in Russia in the second half of the 19th century, both judicial and governmental. (Pomeranz, 2019). In foreign policy, he was primarily a pacific ruler, learning from the mistakes of his over-ambitious father. The beginning of his reign was difficult, but he quickly overcame most of the troubles. In 1861, he emancipated the serfs,

which outlawed forced labour and made them free citizens. He also set a plan to build and develop a network of railway lines that would connect the whole country through the Trans-Siberian Railway. Primary and secondary education were made easily accessible, and universities were given teaching independence from the crown. By the end of his reign, Alexander considered abandoning autocracy and becoming a constitutional monarchy like the ones found in central Europe but was assassinated in 1881.

2.2.2 Alexander III (1881-1894)

The source consulted for context on this period was Sebag-Montefiore (2015).

Alexander III was crowned after his father's assassination, and he counter-reformed many of his father's liberal policies. These policies removed power from the peasants and nobility and again placed it on the autocrat. Isolationist and protectionist policies were introduced that put a high tariff on imports and prevented ideas from Europe from entering Russia. The **Trans-Siberian railway**, which his father started, was finished during his reign. This was accomplished with help from the state and brought all of Russia closer, making ruling easier. The state provided subsidies for private companies developing heavy industry in the Urals, Moscow, St. Petersburg and the Donbas. This increased the production of coal, iron and steel considerably.

2.2.3 Nicholas II (1895-1917)

The sources used to construct this point are Sebag-Montefiore (2015), Blinnikov (2011) and Rosefielde (2007).

Nicholas II was crowned after his father's death and ruled until his abdication in 1917. He was then assassinated after the Bolsheviks seized power. Early in his reign, his foreign policy centred around obtaining treaties that guaranteed peace, which allowed the country to develop free of conflict. The Trans-Siberian Railway became fully operational during his reign, an important economic advancement that the previous two Tsars had subsidised.

The Russo-Japanese (1904-1905) war was fought over ambitions in Manchuria and Korea on the Pacific border. The war ended in a Russian defeat with many casualties and a considerable economic loss (Sebag-Montefiore, 2015). Political unrest at home, which developed into the 1905 Russian Revolution. The Tsar had no option but to write a Constitution in 1906.

In 1914, Russia followed its allies into what would become **WWI in response to a series of conflicts**. The war would last for four years and would end imperial Russia. The unrest at home created by the war, compounded by the existing discontent, made the Tsar abdicate. In the Eastern front, in the early years of WWI, Russia suffered heavy losses at the hands of the modern German military and faced supply problems derived from the large terrain expansion.

The Bolsheviks, a Marxist party led by **Vladimir Lenin**, took advantage of the social unrest and seized power from the provisional government in the **October 1917 revolution**. Once the Bolsheviks established themselves in power, they formed the Soviet Union. One of the first orders of action on the Bolsheviks was to negotiate peace with the central powers.



2.2.4 Russian Civil War (1917-1922) & Establishment of the Soviet Union Under Lenin

The source consulted for this section was Rosefielde (2007).

The October Revolution evolved into a civil war in Russia in which the Red Army victory permitted the creation of the **Soviet Union in December 1922**. The new government faced the challenge of rebuilding the infrastructure of a war-torn country with low morale that had sustained eight years of conflict between WWI and the Civil War. To face the issues derived from the war, like hyperinflation, the devaluation of the Ruble, famine and the disruption of industry and trade, the Bolsheviks introduced the **new economic policy (NEP)** in 1921. The NEP would last until the first **5-year plan (5YP)** was adopted in 1929.

2.2.5 Russia 1924-1939 Early Stalin Era

The sources that were used to synthesise this section were Blinnikov (2011) and Rosefielde (2007).

After Lenin died in 1924, there was a 3-year struggle between two factions, one led by Leon Trotsky and the other by **Joseph Stalin**. Trotsky advocated for global communism, avoiding becoming isolated. He also believed in the continuation of Lenin's NEP. On the other hand, Stalin advocated for strengthening the country internally and becoming self-sufficient. By the end of the 1920s, Stalin outmanoeuvred his rivals and established himself as the leader of the Soviet Union. One of his first orders of business was to abandon NEP and establish a **5YP** for the economy that would go on from 1928 to 1932.

Several important global aspects influenced decision-making during the 1920s until the end of the first 5YP. The great depression affected markets globally and meant a substantial downturn in international trade on which the country was still reliant. The rise of fascism in Europe saw a competing ideology close to the European borders. With the invasion of Manchuria, China, the Japanese empire threatened the Pacific land borders.

The first five-year plan was designed to end in 1933. Still, it was abruptly cut in 1932 and declared "prematurely successful" by the Soviet Union, justifying the high levels of industrialisation and the outputs of the energy, natural resources and metallurgy industries. Then, the Soviet Union adopted a **second 5YP** meant to capitalise on the infrastructure set up by the first one. The plan aimed to build and consolidate the current industry by making it more efficient with the goal of increasing the coal, steel, and capital goods industries. It also promoted the building of impressive infrastructure, which doubled as a publicity stunt. Examples are the Moscow Metro, inaugurated in 1935, and the Dnieper hydroelectric station.

During the second 5YP, Stalin consolidated absolute power on his person, a remnant of the years of the Tsars, by increasing repression and starting political purges where political adversaries were sent to forced labour camps far away from the spheres of power in Moscow.



2.2.6 Russia 1938-1953 Late Stalin Era & WWII & Cold War

For this section, the sources from the previous section, Roselfielde (2007) and Blinnikov (2011) have been used. Gladdis has also been used in addition to these two.

In 1938, the Soviet Union adopted a third 5YP, which would continue until it was dragged into WWII in 1941. With the growing threat of war, the industry was evacuated far from the border to the east. The Eastern Front of WWII resulted in immense human and infrastructural loss that would take years to recoup. The Soviets adopted a war economy where the main focus of every industry was to fuel the war machine, most industries were repurposed to produce military weapons or goods, and most fighting-age males were conscripted to face the German invasion. Initially, Nazi troops invaded Russia, advancing territory quickly and seizing industrial and agricultural centres that were critical for Soviet survival. By 1943, the war weakened Germany, and the Soviets launched a counteroffensive. Estimates count the number of Soviet deaths at around 27 million (Davies, 1998). After the war, the USSR adopted a fourth 5YP to rebuild the industry from 1946 to 1950. The main aim was to restore the heavy industry to the levels it produced before the war. Military spending was also crucial due to the beginning of the Cold War.

2.2.7 Russia 1953-1964 Khrushchev & Destalinization

For this section, the main sources used are Blinnikov (2011), Davies (1998), and Gladdis.

Stalin's death in 1953 created another power vacuum and struggle that ended with Nikita Khrushchev as the leader of the Soviet Party in 1955. He denounced Stalin's policies, especially state control. He started a period of destalinisation. To improve agriculture, Stalinist Russia's main weakness, Khrushchev proposed bringing agriculture to unused non-agricultural land in Siberia and Kazakhstan through the **Virgin Lands Campaign**. Khrushchev also introduced a 7YP intending to improve the quality of life, with a considerable emphasis on consumer products. Another key aspect of the period was the investment in the space and arms race with the USA. In 1957, the USSR launched Sputnik, the first artificial satellite, and by 1961, they sent the first human to space. The American Apollo program countered early success in the space race, which saw the USA beating the USSR in the moon landing in 1969.

2.2.8 Russia 1964-1982 Brezhnev Era

When synthesising this section, the sources used were Bunce (2007) and Gladdis.

After a period of rapid progress, the Brezhnev era saw growth stagnate and deflate slowly. Under minister **Alexei Kosygin**, an attempt was made at economic reforms. However, food shortages were the norm during the period. In the 1970s, the **oil crisis** marked economic and foreign policy. Heavy investment was made in the military and the space race; however, once the USA surpassed the Soviet Union, they would never recover. During the Cold War, proxy wars were declared constantly. The most consequential was the **Vietnam War (1965-1973)**. Apart from some conflicts in the Middle East, the next big conflict was the **Afghanistan War (1979-1989)**.

2.2.9 Russia 1982-1991 Late Soviet, Prestroika & Glasnost

For this section, the same sources from the previous section, Bunce (2007) and Gladdis were used.



After Brezhnev died in 1982, the Soviet Union entered a period of instability that ended with its dissolution in 1991. This period saw three leaders who tried to adopt their policies and break with the previous, which proved disastrous. The first president was Yuri Andropov; his main target was ending corruption and the inefficiencies it introduced in the economy. He passed after only 15 months in power. Konstantin Chernenko rose to power in 1984. He had been a close associate of Brezhnev and was seen as a return to the Brezhnev style of politics. His health also declined, and he passed after just over a year in power.

After the death of Chernenko, Mihail Gorbachev was made secretary general. He was president from 1985 until the fall of the Soviet Union in 1991. His three key policies were ***glasnost* (openness)**, ***prestoriika* (restructuring)** and ***demokratizatsya* (democratisation)**. The Gorbachev period was marked by an approach to the West and an attempt at coexistence with arms de-escalation and nuclear control agreements. By 1988, the Soviets withdrew troops from Afghanistan. **The fall of the Berlin Wall and German reunification (1990)** marked the beginning of the end of the Cold War and the Soviet Union and a new era of European politics. By the end of 1991, the Soviet Union crumbled and dissolved into 15 republics.

2.2.10 Russia 1991-2000 Post Soviet Russia Yeltsin Era

For this section, the main source used was Rosefielde (2007).

After the fall of the Soviet Union, a period of great instability started in which certain key ex-Soviet players established their economic power in the new market, seizing financial power in Russia by taking charge of the newly privatised industry. The economy transitioned from centrally planned to market-oriented. The shock change wrecked the economy, and the early 90s were a period of hyperinflation. After an initial recovery period, Russia faced an important economic crisis in 1998, with a devaluation of the Ruble after a decline in oil prices.

2.2.11 Russia 2000-Present Putin Era

For this section, the main sources were Rosefielde (2007) and Blinnikov (2011).

Putin rose to power at the turn of the millennium. His first order of business was to stabilise the Russian economy, which was helped by the global rising price of oil and gas in the 2000s. The government used the money obtained from exporting natural resources and metallurgy to pay off foreign debt and invest in industries similar to those in the Soviet period. The financial crisis of 2008 hit Russia hard, with oil prices falling. The government had to intervene with fiscal stimulus and investment in industry. This showcased Russia's dependence on the export price of natural resources and the fragility of its economy. In the 2010s, Russia grew more isolationist, culminating in the 2014 annexation of Crimea.



2.2.12 Context Summary

The following table summarizes the historical context, defining the most impactful events of each period on the NIS.

Figure 2. *Summary of the historical context.*

Period	Critical Events for the NIS
Nicholas I & Alexander II (1825-1881)	Crimean War (1853), Emancipation of the serfs (1861), Alexander II assassination
Alexander III (1881-1894)	Finalization of the Trans-Siberian railway, Counter Reforms
Nicholas II (1894-1917)	Russo-Japanese War (1904), WWI (1914), Nicholas II assassination (1918).
Vladimir Lenin (1917-1922)	Russian Civil War (1917), NEP (1921)
Josef Stalin (1924-1953)	5 year plans, WWII (1939), Start of the Cold War
Nikita Khrushchev (1953-1964)	Virgin Lands Campaign, Sputnik launch, (1961) Apollo moon landing (1969)
Leonid Brezhnev (1964-1982)	Oil Crisis, Vietnam & Afghanistan War
Mikhail Gorbachev (1982-1991)	Fall of the Soviet Union
Boris Yeltsin (1991-2000)	Transition to a market-oriented economy, Ruble crisis (1998)
Vladimir Putin (2000-Present)	2008 global financial crisis, annexation of Crimea (2014)

3. NATIONAL INNOVATION SYSTEMS

In this section, the term **National Innovation System** will be discussed. From now on, it will be referred to by its initials NIS. First, the concept will be contextualised by giving an overview of the history of NIS research, and the most prominent definitions of the term will be exposed. The term will be defined in the context of this analysis with the aid of academic definitions.

3.1 EVOLUTION OF THE TERM

The term NIS has been developed over the last 200 years to spotlight the role of innovation in economic growth and the competitiveness of nations. Since the 1950s and especially after the 1990s, policymakers have used it to guide scientific and innovation policies.

Figure 3. *Evolution of the NIS term*



3.1.1 Precursors to the Term

Some 19th-century and early 20th-century economists have researched the concept of NIS without explicitly using the term. They have influenced further research, and their work has been critical for developing NIS theory (Freeman, 1987).

3.1.1.1 Friedrich List

List's book "The National System of Political Economy", published in 1841, emphasises the government's role in a nation's economic development and advocates for innovation, favouring policies that help create a national innovative environment. The book introduces some history of the economic policy of nations such as Renaissance Italy and Hanseatic Germany (List, 1841).

It describes the intangible resource a nation has in its "*accumulation of discoveries*" to explain why one country may be more economically prosperous than another over a certain period. He also describes this as the "*mental capital of a country that is an asset that can be accessed*" and emphasises "*the importance of the involvement of the whole society*". The role of **education as a productive economic activity** is also introduced, arguing that it contributes to the economy, although it is intangible. List acknowledges that "*a close interaction of the commercial, scientific, social and civil spheres is necessary*" to create an optimum environment (List, 1841).

3.1.1.2 Joseph Schumpeter

Schumpeter is among the earliest proponents of including history to challenge classical economics. He proposes that historical events have long-lasting effects on society for many ages and influence the conditions of technology and technology itself. He is among the first to describe the innovation process as a system with a set behaviour, actors and stock.

He also coined the term **creative destruction**, which is then referenced by the next generations of economists when talking about innovation. He acknowledges how a capitalist system can't be static and that *"innovation keeps the capitalist engine moving"*. Both hint at the idea of a system of innovation (Schumpeter, 2003). Creative destruction is the process whereby the current status quo is challenged and then replaced by innovation, which becomes the following status quo. This process is repeated over time, following a predictable behaviour pattern that he describes as an **organic system**. Schumpeter refers to diffusion borrowing from biology as assimilating and propagating new knowledge from an area of high density to one of low density.

3.1.1.3 OECD Frascati Manual 1962

In the 1960s, the OECD had a series of meetings in the Italian town of Frascati after realising the importance of R&D in policymaking and the need to **standardise innovation surveys** to measure effective policymaking over time so that R&D systems can be compared and analysed. (OECD, 1962). The manual proposes using **Gross Domestic Expenditure on R&D (from now on, GERD)** filtering by different parameters as a metric to measure the inputs the R&D industry has in the given period. A measurement of the ratio of government R&D spending to other expenditures GERD/GNP is also proposed (OECD, 1962).

3.1.2 Definition of the term in the 90s

Freeman, Lundvall and Nelson are all credited with independently defining the term national innovation system. By the 1990s, the term had gained popularity amongst policymakers and had become an essential point of study and action for international organisations like the OECD or the EU.

3.1.2.1 Christopher Freeman

Freeman is a British economist who built on Schumpeter's work in the 1970s and defined innovation as *"an essential condition of economic progress"*. He expands on Schumpeter's actors and defines government, the R&D lab at the university and industry. He places great emphasis on the dissemination of knowledge within the system. Freeman compliments List's ideas on policy-making in his pursuit of industrialisation. He credits List with being the first to think about the interdependence of the system actors and investing in knowledge accumulation.

In his book, **The Economics of Industrial Innovation (1987)**, Freeman describes different periods in modern history and the innovations that have come out of these periods. He bases the periods on Schumpeter cycles. For each period, various countries are compared on metrics that affect the innovation of the given period, and hypotheses are made as to why innovation has been more prevalent in some countries than others. Freeman defines the NIS as *"the many interactions between various institutions dealing with science and technology as well as with higher education, innovation and technology diffusion in the much broader sense."* The critical point made in this definition is that institutions interact with each other to spread knowledge.

3.1.2.2 Bengt-Ake Lundvall

Bengt-Ake Lundvall is a Swedish economist who is often credited with creating the term National Innovation System in 1985; as with Freeman, his work is also influenced by List and Schumpeter and builds on the existing ideas around innovation in the late 80s and early 90s.

Lundvall defines the NIS as the elements that aim to produce and diffuse “*new economically useful knowledge*” and the relationships amongst those elements. Apart from the system at a national level, Lundvall also sheds light on the importance of regional systems as smaller units of the systems. He defines the actors in the system as institutions, R&D labs and universities and what he calls “**national idiosyncrasies**” as a crucial element of the system: the internal organisation of firms, inter-firm relationships, the role of the public sector, the institutional set-up of the public sector, and R&D intensity and organisation.

3.1.2.3 Richard Nelson

Richard Nelson is an American economist whose book **National Innovation Systems: A Comparative Analysis (1993)** studies the national systems of 15 countries, differentiating by size and income to give a wide array of NIS. This current work aims to perform a comparative analysis of Russia concerning other countries. Amongst the countries studied are varied nations such as Britain, Denmark, and Brazil. Nelson defines a NIS as a “*set of institutions whose interactions determine innovative performance,*” with innovation being a broad term that includes activities and investments that aim to introduce a product or process. Nelson, however, makes a distinction in that he refuses to focus solely on the Schumpeterian innovator, the first mover. Nelson commends Schumpeter and brings to light two important aspects of his thesis: the importance of competition through innovation and how a nation can gain competence and a comparative advantage. The other is an important stress on the importance of temporal monopolies that arise from innovation.

3.1.2.5 OECD Oslo Manual 2002

This manual gives governments and policymakers guidelines for collecting and interpreting innovation data. It acknowledges that innovation is critical for the growth of a nation.

The manual describes the crucial role that the linkages amongst actors of the system play, being as important as the actors themselves. It also highlights the diffusion or spread of innovation within the system. The main actors identified are firms, government laboratories, policy departments, regulators and customers.

3.2 DEFINITION OF NATIONAL INNOVATION SYSTEM

3.2.1 Definition of a system

A system is a set of coherently organised things interconnected to produce a pattern of behaviour that persists over time. Different parts of the system affect each other in a way that they would not individually (Meadows, 2008).

The main elements of a system are:

Figure 4. *Elements of a System*

Element	Definition
Stock	The amount of something the system creates; can grow and deplete as the different elements interact.
Loops	Points where a behaviour within the system is reinforced, resulting in an exponential growth or depletion of stock.
Flow	Defines how information is shared amongst all the parts and is measured as a rate.
Leverage points	Points where the system can be affected with very little input from any of the parts of the system. They can make or break a system.

Source: Meadows (2008)

3.2.2 Definition of Innovation

Innovation is bringing **novelty into a realm of knowledge** that brings something new or a considerable increment to the existing knowledge. When successful, it may bring Schumpeterian creative destruction and replace the status quo. Innovation can take many forms; however, innovation is within the scope of this work. refers to TTP innovation. The base from which innovation starts is the current knowledge pool, and once the innovation becomes public, it gets added to the same knowledge pool, creating a loop. Freeman refers to this as “*know-how accumulation*” (Freeman, 1987). **This constitutes a positive feedback loop.** Information is intangible, but when modelled, it has three dimensions: **the quantity**, measured as the amount of domain-specific knowledge; **the quality** of the knowledge, which is how clear and reproducible it is; and **how many people in the system possess it.**

3.2.3 Elements of the NIS

The **knowledge stock of the system** is the accumulated knowledge, both specific and non-specific, that all the actors in the system possess together. In this system, the stock is intangible and must be measured using derived metrics. Flow is **how knowledge is diffused, assimilated and applied by the system.** Loops are elements of the system that **fill or deplete the knowledge stock.** As the final objective of the system is to accumulate and increase knowledge, a positive loop will increase the knowledge stock, and a negative one will slow down the rate of knowledge increase. Leverage points are those points where action results in a more significant change in the system; these will be events that shape the system, such as wars,

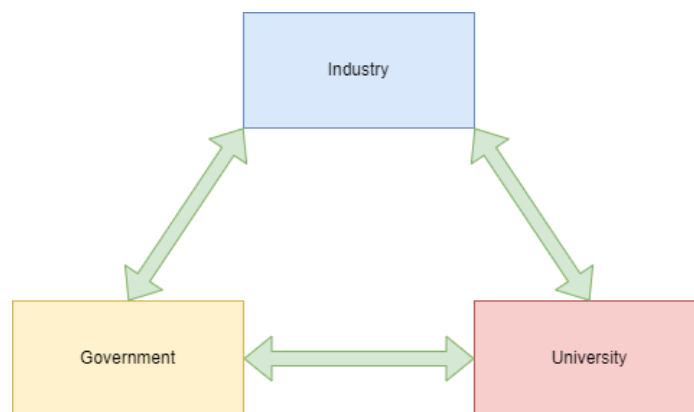
political turmoil, or outside competition. Actors are the different parts of the system that interplay to affect the system's behaviour.

3.2.4 System Actors

One of the simplest models for interplaying actors is the **triple helix framework**, defined by Etzkowitz and Leydesdorff (1998), which borrows the spiral shape of a DNA molecule as a metaphor for the intertwined relationship of academia (universities), industry and government. Further, the **quadruple helix** adds another strand that, while keeping the system relatively simple, adds another dimension to the system analysis by including the public. As mentioned before, society plays a vital role in becoming a feedback loop and storing the knowledge stock.

Therefore, the actors who will receive focus are **industry**, represented by private business firms, especially those participating in innovative activities. **Academia** is represented by places of higher education and vocational training schools that provide research and training for skilled labour. **The government and its institutions**. Finally, **society**, which plays a significant role in accumulating knowledge, with culture and tradition of innovation. Infinite strands can be added to the Helix by adding more system stakeholders, making the system more complex, and giving more information. Some examples of this are NGOs or the media.

Figure 5. Triple helix model of NIS actors.



4 Comparative Analysis

This work aims to assess how the historical context affects the development of the Russian NIS, finding a way to measure development then becomes a critical aspect of the job, as well as being able to use other NIS as a control to evaluate how much the historical context has affected the development. In this section, ways to compare NISs will be explored, and an analysis of the development of the Russian NIS will be performed.

4.1 Approaches to Analysis

Multiple approaches have been contributed to the analysis of the National Innovation System to measure progress and compare different systems. Policymakers like the OECD have contributed some, and some have been academic. The metrics used to measure the elements of the system and the period over which the system is measured must be defined.

In this section, several different approaches to measure the system will be proposed, which will then be used to assess the development of the Russian NIS and how it has developed compared to other NISs.

4.1.1 Nelson

Richard Nelson, who was introduced in the previous section, is one of the first to make an academic comparison of NISs. One of the nuances of the comparison is dividing the countries into different categories according to size and income, and this distinction emphasises the heterogeneity of each system (Nelson, 1993).

The proposed approach uses a set of fixed metrics to study the system but then highlights what makes the NIS different from the rest. Assessing the NIS individually before comparing it to the whole allows us to define what competitive innovation means within the system and understand the conscious decisions taken to develop the NIS.

The commonalities found amongst competent NIS, regardless of their individual idiosyncrasies, are highly competent firms in the industry, which in most cases comes from the investment, a good set of domestic customers for the innovative industry, education that provides this industry with a steady flow of qualified workers and exporting to be attractive to firms, so there is no total dependency on the home market.

4.1.2 Patel & Pavitt

Patel and Pavitt (1994) build on the work of Lundvall, Nelson and Freeman and evaluate the necessity and methods to compare a NIS, acknowledging the difficulty of the task and the problem of reduced data. The main reason for the differences in NISs is that **international diffusion of knowledge is not automatic, simple or costless**. Technical accumulation of the different systems has led to technological gaps in which a country is considerably more competent technologically than another. Different incentive systems can explain the reasons for these technological gaps in the different NISs, which is how the system actors use feedback loops.

One reason for explaining the gap is how different one NIS is from another regarding technological competence. Here, things like the range of goods one can produce, how efficient production is, and the range of possible alternatives are discussed. The authors propose to measure different metrics for each actor so a picture of the system can be painted as a whole:

- Business firms propose to measure R&D activities and patent grants, citing the OECD Frascati manual, and the authors suggest using data like **GERD statistics**.
- For universities, they again propose to measure R&D inputs and outputs, focusing on the number of **papers published and citations**. The authors acknowledge that this lagging metric relies on previous innovations for the outputs.

The authors propose two different kinds of systems in terms of growth: myopic and dynamic systems. **Myopic systems** are characterised by allocating investment to respond to a market necessity and treating investment in R&D as a traditional investment. The authors define the US and the UK as myopic. **Dynamic systems** recognise that R&D investment is not equal to traditional investment and that not only tangible output is generated but that the intangible knowledge accumulation that results from this investment creates a build-up of competency that can fuel further investment and compound. Examples given are Japan and FR Germany.

4.1.3 Chaminade Lundvall & Haneef

Chaminade, Lundvall & Haneef (2018) propose a hybrid approach that combines quantitative and qualitative analysis of an NIS. Qualitative analysis was the initial approach in the 1990s for studying specific NISs, with a strong element of finding what makes the system unique. Qualitative analysis of historical factors is often critical to provide insight into the system's workings. However, when there are no metrics, there is a risk that it won't be possible to use them to make and measure policy. Quantitative analysis considers social institutions, financial systems, education and infrastructure. It is favoured by policymakers and popularised by the OECD.

4.1.4 Bergek et al.

Bergek et al. (2008) proposed the most widely used modern approaches to qualitative studies of NIS. The paper's authors propose a system that acknowledges the traditional approach and the needs of policymakers. It proposes a 6-step framework:

1. Define the technological innovation system in question.
2. Identify the structural components, the actors of the system
3. Identify the structural functions of the system and the functional pattern. This is the aim of the system and its reason to exist.
4. Assess how well these functions are being fulfilled within the system
5. Identify enablers and obstacles of development towards the desired functions
6. Specify key policy issues that block development.

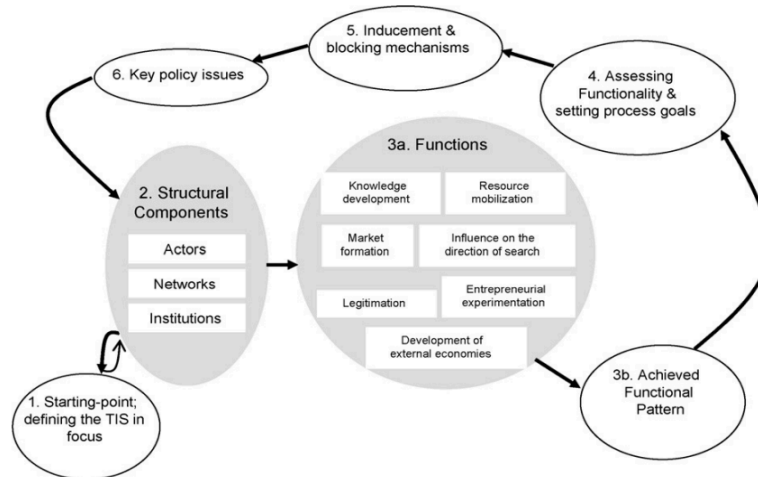
The following table describes the functions used to describe the functional pattern of a NIS:

Figure 6: Definition of the NIS functions.

Function	Description
Knowledge development	How new knowledge is created and diffused.
Resource mobilisation	Availability of resources that support innovation.
Market formation	How easy is it to create or accommodate existing demand for the output of new knowledge?
Influence and direction of the search	The direction of the innovative efforts by shaping incentives and goals.
Legitimation	Social and regulatory support for innovation.
Entrepreneurial experimentation	How easy it is to try and implement new ideas. This acknowledges the trial-and-error aspect of knowledge formation.
Development of external economies	Possibility for the generation of profits outside of the NIS.

Source: Bergek et al. (2008)

Figure 7: Diagram of the functional system of analysis.



Source: Bergek et al. (2008)

4.1.5 Global Innovation Index

The Global Innovation Index (GII) is an index that was started in 2007 and published by the World International Property Innovation Organisation. It measures how innovative a country is using objective and subjective metrics, using both input and output data (WIPO. GII Reports 2011-2023). The different metrics are divided into pillars and sub-pillars and make up a valuation that ranks the country in the global sphere. Pillars are broad key metrics, and



sub-pillars are specific metrics that fall under the definition of the wider metric. The score for a pillar will be the aggregate of the sub-pillars.

The following table describes the pillars and sub-pillars of the GII:

Figure 8: Pillars of the GII report definitions.

Pillar	Sub Pillars
Institutions	Institutional, regulation and business environments
Human Capital and Research	Education, tertiary education and R&D
Infrastructure	ICT, General infrastructure and sustainability
Market Sophistication	Credit, Investment, Trade diversification and market scale
Business Sophistication	Knowledge workers, innovation linkages, knowledge absorption
Knowledge and Technology Outputs	Knowledge impact, creation and diffusion
Creative Outputs	Intangible, creative goods and services

Source: GII Report

4.1.6 Schumpeterian Periods

The choice to separate the different periods of comparison according to the Schumpeterian periods answers to the differences in the periods of innovation and the actors involved in the innovation. The historical periods don't align with the global waves because Russia has not aligned with the global stage for innovation and has lagged for most of its history.

The following table describes the Schumpeterian periods and their key characteristics:

Figure 9: Schumpeterian periods definition.

Period	Period	Key Industries
First Industrial Revolution	1780-1840	Textile, coal
Steam and Rail	1840-1900	Steam, rail, iron, steel, telegraph
Electricity and Chemicals	1900-1950	Electricity, Automotive, chemical, telephone
Petrochemicals and Electronics	1950-1990	Oil, plastics, semiconductors, consumer electronics
ICT	1990-2020	Internet, PCs, mobile phones

Source: Capitalism, Socialism and Democracy, Schumpeter (2003)

4.2 Comparative Analysis by Period

In this section, using the comparative analysis tools and the periods presented in the previous section, an analysis of the development of the Russian NIS will be performed and benchmarked against different countries within the same period. This will ultimately be used to discern the impact of historical context on the development of the system.

First, the state of the NIS at the beginning of the study period will be exposed (4.2.1). Then, the study will follow a chronological exploration of how the historical context influenced the Russian NIS, exposing the main historical events of the period and how they shaped the NIS. The study will start with the ending of the second Schumpeterian wave (4.2.2), a period marked by political instability within Russia. From here, the third Schumpeterian wave will be studied (4.2.3). During this period, the NIS is affected by 2 World Wars, a civil war ending in a change of government and, at the end of the period, the start of the Cold War. The next study period (4.2.4) is when the post-stalinist USSR, the Cold War and the Space Race define the NIS. By the end of this third period, the NIS is shaken by the decline and fall of the Soviet Union. The final period to study (4.2.5) is the current Schumpeterian wave, marked by the creation of the Russian Federation, two financial crises and a military conflict escalation in Ukraine.

4.2.1 State of the NIS before 1875

The Tsarist economy before 1875 was characterised by a constant catch-up with the great colonialist powers of Europe in terms of innovation and industrialisation. The lack of reliable data from this period means that a qualitative analysis of the functional type will be the most efficient way of analysing the system.

During most of the tsarist period since Peter the Great, great prestige was put on the European intellectuals, especially from Germany, who brought foreign innovations to all areas of society. The role of follower, in a time when communication was slow, made Russia lag behind the rest of the powers and created a great disparity amongst regions within Russia, with the regions closer to the European border benefiting from the slow diffusion that emigration and exports achieved and the Pacific region having a substantial technological gap with the Eastern regions like Moscow or Kyiv. The size of the country and the poor infrastructure meant that there was a minimal network.

The first industrial revolution started in Britain in the 18th century and gave the country a competitive advantage still being exploited today. Britain was the main power globally, covering the globe through colonial rule where resource extraction could be used to fund the home innovation market. By the early 19th century, the knowledge of the steam machine introduced by James Watt in 1784 was diffused into continental Europe. The textile, coal and rail industries experienced quick growth with this industrialisation.

Russia was mostly an agrarian country during this period. Its borders allowed and even incentivised the permeation of knowledge, but the communication infrastructure could not support successful diffusion; it took more than 20 days for the information to travel from one side of the country to the other (Madariaga, 1996). The country's main competitive advantages were its size and population, but it was not appropriately leveraged.



The second industrial revolution was launched by introducing rail, which created a necessity for better extraction of steel and iron. It also introduced a new means of communication in the telegraph that supported the construction of longer railway lines as communication was eased during the infrastructure construction progress.

The communication infrastructure was non-existent in Russia, where the Tsar used the limited rail exclusively. On the other hand, the USA, which is similar in size to Russia, experienced a boom in the railway industry after the American Civil War (1861-1865). The government offered land and subsidies to private industry to create a railway network that was over 100000 km, which helped the movement of goods and the development of remote areas.

To put Russian lag into perspective, the trans-siberian railway joining the East and the West of the country didn't officially start being built until 1891. It was not finished until 1916, nearly 50 years later than its American counterpart. Both railways played a similar part in that they joined the more populated regions of the country to the less populated but resource-rich areas. The rail allowed the countries to leverage industry and offer new opportunities that had been impossible years before. It allowed the movement of goods from industry centres or ports inland with minimal effort, which allowed quick development of new infrastructure, and it also reduced the time of communication within the country.

In 1837, James Morse invented the telegraph in the USA, allowing instant communication across great distances and ensuring unprecedented knowledge diffusion speed. By 1861, the private sector had transcontinental telegraph lines in the USA. Telegraph use was commoditised and used indistinctively for government, commercial, and personal uses. Britain was another early adopter of the technology, with many cities being connected through telegraph lines. By 1866, a transatlantic line had been laid that connected the USA with Britain. In 1870, Britain nationalised the telegraph industry and put it under the jurisdiction of the post office. Russia began developing the telegraph later than the rest of the industrialised world, and the infrastructure was concentrated in the European region of the country. The availability to the public was severely limited, and it was only used for government and military cases.

Education was not socially valued, and it was mostly military-based and directed to noble males; Moscow and St Petersburg universities were established in the late 18th century and tried to emulate other universities further East, like Kyiv University. They were created to educate the nobility domestically. However, most of the educated elite in Russia went abroad to study, especially in Germany and Britain. By this time, other countries, like Britain, already had an established university system within the country that had around 400 years to establish and develop. In the early 19th century, an effort was made by the Russian government to offer higher education in the major cities and some of the territories where they had expanded, like the Baltics. This is a clear aspect of Russia that lagged aggressively behind the rest of the powers. Western European university synergies had a legacy of centuries between them and the other actors. It would take Russia nearly 100 years to create a network of universities that interacted within a system.

By the end of the 19th century, the people demanded change in Russia, and the amount of social and political insecurities put the Tsar's authority into question. Autocratic monarchy gave Alexander the whole power of government with no constitutional limitation, and the secret police was active in persecuting political dissidents and revolutionaries. By this time, in The Victorian era in Britain, the monarchy was constitutional, and the Queen was a figurehead with most of her powers being limited. Real political power resided in a democratically elected



parliament and prime minister. During the 19th century, suffrage movements augmented the number of people who could vote in Britain. France faced a period of instability, but it was governed as the Third Republic. Germany, the country the Russian people looked at aspirationally, was a Federalist Constitutional Monarchy where the different states had some autonomy. The ruler, however, was still an emperor, and the powers of the elected parliament were severely limited. The USA was a federal republic with extended suffrage and a similar approach to civil liberties to the French, where citizens had a high degree of freedom of speech and freedom of the press.

List (1846) studied the national system of imperial Russia as part of his study. List emphasises the Russian dependence on ports, like Novgorod, which allows trade with the wealthier European nations. List describes the improvement in infrastructure that Russia had experienced in the previous 140 years in communication infrastructure like canals and roads to aid foreign trade. Finally, he also describes a periodic trend. At first, peace meant Russia scale foreign trade, but as conflict increased, it turned back to overreliance on its domestic industry.

Key Point

The main characteristics of this period are Russia's lag in all the significant metrics of industrialisation with Western Europe, the growing social unrest, and the questioning of the Tsarist authority.

4.2.2 Comparative Analysis Second Industrial Revolution 1875-1900

In 1875, Alexander II's reign was ending, the social situation within the country was unsustainable, and the Romanov line was in decline. The Crimean War depleted the Russian economy, and the territory in Alaska was sold in 1867 to raise money to continue supporting the war machine. Elsewhere, the second industrial revolution was already underway through improved extraction methods in the metallurgy industry, which split into other industries.

Alexander's main aim as an autocrat was to maintain his position, and most of his policy was directed towards appeasing the social turmoil. One of his first orders of business was to free the serfs, which ended forced labour and started a judicial reform, liberalising Russia and introducing private law to incentivise economic growth. To serve as a comparison, the USA had abolished slavery 100 years before. The emancipation of the serfs meant that these people were not bound to land, and they could move to urban centres in search of a better labour market. This resulted in the concentration of population, knowledge, and industry around hubs, especially St. Petersburg and Moscow, which shaped the NIS and is still present today.

In the 1870s and 1880s, the Tsar supported regulation and investment in rail building. It was necessary for a modern industrialised country, and this was one of the areas where Russia was lagging behind Europe and the USA. Russia was playing catchup, but it could use its large iron and steel industries to build the rail, which was built using a state-regulated plan and investment. The government made policies to support the growing rail industry by giving loans and, more importantly, imposing high tariffs on foreign rails, meaning that the raw materials used would be domestic. However, as we have seen in the previous section, the rest of the world was already enjoying the benefits of the rail infrastructure. It was using those same benefits to develop other capital goods industries further. (Davies, 1998)



The government encouraged industrialisation, and with the help of the development of infrastructure and the existing natural resources reserves, Russia experienced an industrial boom that saw the rate of industrial production rise between 8 and 9 per cent yearly during the 1890s. The Ural and Donbas regions were developed, and steel and iron extraction was improved using German techniques that had permeated through the border. At the beginning of the period, in 1877, Russia produced 250000 tonnes of pig iron yearly; by the end of the period, at the turn of the century in 1899, the production had risen to 2700000 tonnes yearly (Davies, 1998). This increase of over 1000% was used to finance other industries and invest in capital goods that improved the NIS, as many Western European countries had previously done.

Another major technological advancement, the telephone, was patented in the USA by Alexander Graham-Bell in 1876. The patent allowed Graham-Bell to secure the profits of his invention and to allow the diffusion of the invention through easy commercialisation. The inventor developed the ideas of other scientists and innovators like Edison, Faraday, and Morse and leveraged the existing electric telegraph infrastructure that had been in place since the 1840s and the extraction of copper. The Russian NIS lacked the expertise, infrastructure and institutions to achieve this innovative feat.

In 1881, Alexander II was murdered by a group of revolutionaries in St Petersburg after several previous attempts on his life. The consequences of this assassination would echo for several decades. Alexander III was more conservative than his predecessor; he implemented several policies to consolidate power, which backfired horribly and ended in the 1917 Bolshevik Revolution. His policies included an abolishment of the reforms of the previous Tsar and increased central control and censorship.

The perceived external threat and the closeness of perceived enemies in Russia's borders convinced Alexander to invest heavily in the army and military infrastructure. To achieve this, he implemented a policy of "russification" that had lasting consequences for the country. Russian was the state's main language, and cultural diversity was restricted. This made the country less attractive to foreigners and reduced the diffusion of knowledge at the Eastern border, increasing the technological gap. Alexander III became suspicious of foreign influence on revolutionary ideas. He started a policy of self-sufficiency and reduced reliance on foreign investment and imports in favour of the domestic market.

The end of the period is marked by the first period of the reign of Nicholas II, the last Tsar of Imperial Russia. Nicholas was made king after the unexpected death of his father and was crowned with only 26 years. His inexperience increased the questioning of his authority. He is often described as indecisive (Sebag-Montefiore, 2015). Nicholas tried to compensate for his questioning with an expansionist policy, trying to win popularity through military victory and annexing Asian territories. His initial pursuits in Manchuria proved futile and would lead to conflict with the Japanese Empire.

In 1892, the former railway minister, Sergey Witte, was promoted to finance minister. He is one of the most important figures of Nicholas' early reign and offered his competence in the areas the Tsar lacked. He was the leading promoter of the investment and protection of the heavy industry that experienced a stark growth in the 1890s and saw the finalisation of the Trans-Siberian railway. He also tried stabilising the volatile Russian currency by adopting the **gold standard in 1897**, increasing the confidence in the ruble domestically and through foreign investment. Witte incentivised foreign investment from Britain or France to finance



infrastructure and Russian industry. His policy sometimes clashed with the autocratic rule, and he was fired from the post in 1903.

Key Point

The main event of this period was the Trans-Siberian railway building, which helped significantly bring the remote areas closer to St Petersburg and started Russian industrialization. Secondly, the emancipation of the serfs helped the liberalisation of Russia and brought judicial reforms.

4.2.3 Comparative Analysis Third Industrial Revolution 1900-1950

This section is characterised by the industrial innovation in the extraction and treatment of steel, the mass adoption of electricity and the introduction of long-distance communication through the telephone. The period is one of the bloodiest periods in recent history and is characterised by the political clash of different ideas and regimes that translate to military conflicts. Apart from many minor wars between countries fighting for expansion, WWI and WWII are contained in this period, and their influence will be capital on global NISS. The period ends with the start of the Cold War and the beginning of the arms and space races.

The early 1900s only served to increase the popular mistrust of autocracy. The Tsar's expansionist policy in Manchuria and Korea evolved into the **Russo-Japanese War (1904-1905)**, which Nicholas believed would increase his popularity. However, the war cost Russia dearly and was strongly opposed by the population. The war was a logistical nightmare that depleted the Russian treasury. The productive machine was centred on the Eastern border, around 9000km away, as were most of the military infrastructure and population centres. Moving troops, machinery and supplies proved a complicated and expensive task even though it was aided by the recently finished Trans-Siberian railway. To finance the war, Russia took out foreign loans, especially from France, which increased debt and its dependence on the stability of European markets. Sergei Witte's reforms and proposals for industrial development were stopped to serve the military, and industrial resources and manual labour were diverted to the Western border. This led to delays in the non-war-related industries that had been flourishing for the previous 15 years. The war led to an increase in inflation and more food shortages, which increased the social tension and the questioning of autocracy. The NIS was severely affected by allocating funds to a petty war and by the civil unrest that the war created. All of the previous industrial feats of the previous decade were stopped abruptly when they were starting to achieve maturity. They were diverted to the military, which had little concern for innovation.

The war was doomed from the start, and it was a costly mistake; the loss in the Russo-Japanese war was the final straw for the Tsar's authority, who could not save his position and after the defeat in 1905, the Russian people revolted peacefully through strikes and protests. The strikes disrupted industry, and Nicholas had no choice but to install a constitutional monarchy and increase freedom of speech, allowing parties to form contrary to the Tsar. However, Nicholas still held much power over matters like military and foreign policy and could veto any decision of the legislative assembly. These halfway measures were good enough to buy Nicholas more time in office. Still, they gave a legal voice to the more radical voices within the country and paved the way for establishing Bolshevik rule and the Soviet Union. This, however, was good for the NIS as the institutional improvement returned industrial labour to normal function and incentivised the permeation of thought that was before prohibited through the Western border.



In contrast, in 1904, the USA started to build the Panama Canal, showcasing a peaceful foreign policy aimed at strategic and economic growth at zero human cost. The Panama Canal was an engineering megaproject that considerably reduced the cost of shipping goods for Americans and globally. After the canal opened in 1914, just before the break of WWI, U.S. maritime trade skyrocketed, boosting industries that relied on ship travel, like the energy or metallurgy industries. The USA also benefited from the derived knowledge acquired in a program of these characteristics, and the knowledge could diffuse into other industries easily.

After Wiite, **Pyotr Stolypin** took control of the Russian economy. Stolypin's period as prime minister went from 1906 until the start of WWI. It was characterised by agrarian reforms that tried to increase the private ownership of farmland to make the primary sector in Russia more efficient and modern. Early results of the reforms were successful, and agricultural output increased, but it also increased the social inequalities in the Russian population. It also contributed to a rural exodus that increased the importance of urban life and the creation of industrial hubs. The system was not allowed to mature as its development was cut by the declaration of war and the need to allocate resources to the war economy.

By 1913, Russia accounted for 8.3% of the world's GDP, only surpassed by the British Empire. It was recuperating, and things looked stable. Then, in 1914, WWI broke out in Europe, and Russia was called to defend its allies. Although the early popular response to the war was favourable at home, with lots of publicity for patriotism, early defeats took a toll on morale. By March 1917, Nicholas II felt the situation was no longer sustainable and was incapable of reverting it, so he abdicated the throne.

Once the war broke, Russia's weaknesses started to show, similar to what had come to pass 10 years earlier in the Russo-Japanese War. Communications were far behind those of the rival countries, and industry was less developed and efficient. Transport and communications were especially unevenly balanced between the countries involved in the war, and they proved to be a critical advantage to win the war. The industry was redirected towards producing military goods, but the change was abrupt, and the industry was not prepared. Russia was always short on critical supplies, contributing to the defeat (Sebag-Montefiore, 2015). Agriculture was also hit hard, and 1916-17 saw widespread famine. Other countries involved in the war followed a similar plan to Russia but had a system in place that could cope with the demands of war. The country that came out of the war most successful was the USA, which acted as a lender for most of the war, had no fighting on domestic soil, experienced great economic growth and a step up of its NIS during the war.

In 1917, after the abdication, a provisional government was established, and the main focus for Russia stopped being WWI, which they abandoned, accepting defeat at the treaty of Brest-Livorsk, which meant important territorial losses for the newly formed Bolshevik government. These included key regions for the industry; Russia lost the Baltic States, Ukraine, Belarus and parts of Finland and Poland. The focus changed to the Russian Civil War between the Communist and Continuitist factions that tore the country in two and deepened the already dire situation after WWI.

The first actions of the Bolshevik government were to establish a war economy and to try to establish their position in government while introducing communist policies into the Russian economy, with a focus on winning a civil war, taking precedence before ideology. Government price control was instituted, and it would stay like this for 70 years. This stabilised the currency



after inflation caused by the war's financing. Industrial production fell drastically in both territories controlled by the Bolsheviks and the opposition (Davies). In 1913, Russia had around 136000 specialists with higher studies. After the war and during the Civil War, a majority emigrated or were killed on the battlefield. Russia had few researchers and innovators in the 1920s to guide industry and rebuild the NIS to the pre-war levels. Other countries were able to bring back their innovation apparatus shortly after the end of the war, which further increased the already big gap between Russia and the other powers. To make matters worse, in 1921-22, the situation worsened with a country-wide famine.

War is a big leverage point for innovation, and the bigger and longer the war, the bigger influence it has on the NIS. War sees lots of innovation that echo in the years after. It puts the NIS under big stress because it is obligated to produce constantly for the military machine while sustaining human and infrastructural loss. The NIS is continuously challenged, and through these constraints and adversities, it can learn and improve, seeing a post-war boom. War is a self-reinforcing loop for NIS; it either improves or completely wrecks them. In this case, the war had devastating consequences on the system that were still felt nearly a century after.

The Bolsheviks had three constitutions, one in 1918, one in 1924 and one last in 1936, all a front for one-party governance. Communism was a change of ideology in government, but in reality, decision-making was still centralised, and an authoritarian government was in charge of the NIS. The country was far from what it had been in 1913 (Davies, 1998), with steel production at 4% and foreign trade at 1%. To try to compensate for the situation, Lenin introduced the NEP, and trade was allowed within the country, with the surplus of the government quota allowed to be sold privately, creating a limited market. The NEP stabilised a country that had suffered dearly and allowed a Russian NIS to start to form again from the ashes of the tsarist infrastructure, but it was cut prematurely when Vladimir Lenin died in 1924.

After a power vacuum that caused political instability, Joseph Stalin became the prime minister of the Soviet Union. Stalin achieved double the GDP by 1935 and used it to fund the military complex, using mining and factories as the base.

Collectivisation was used to supply food and control peasants. The industry was used to support agriculture by building tractors exclusively for domestic use. In 1929, 1800 tractors were built by the government, and by 1937, 66500 were built yearly. This industry expertise proved invaluable when it had to pivot to military production in a similar way that the German automobile industry pivoted during the years before WWII—by 1927, agriculture had surpassed pre-war production (Davies), according to most sources.

The government decided industry would be developed through agriculture; investment was proposed in agriculture, and then exported grain could be used to pay for machinery from abroad. As early as List, there are ideas against changing raw materials for manufactured goods as it is an unsustainable growth method. Although everyone within the central planning government agreed that the objective was industrialisation, there were many opinions on how to achieve it, which created instability in the direction of the plan. Russian governance was very aware of the technological gap and was not interested in sustainable ways to close it; Stalin declared in 1931 that Russia was *"50-100 years behind the advanced countries"* and that the gap had to be *"closed in 10 years"* before an eventual invasion.

Stalin developed a 5YP for the industry, another attempt from a central planning system to get the economy and NIS to the level of the Western powers. The first 5-year plan was supposed to



span from 1928 to 1933, but it was cut short in 1932. This lack of patience and pressure for output had been a constant carried on from the tsarist economy, and it is a problem that still today is deeply ingrained in Russian decision-making. The main focus of this first 5YP was rapid industrialization with a focus on capital goods used to further industry, like machinery, vehicles, factories and natural resources. The agricultural side of the plan paid for all of the industrial positives. This was paid down the line when a bad year in 1932 developed into a famine that killed an estimated 5 to 7 million people. (Davies, 1998).

The first 2 years of the plan offered good results as lots of foreign assistance was procured, introducing foreign know-how into the Soviet NIS. The energetic industry was booming, with Azerbaijan becoming a central extraction point for fuel and the Donbas oil fields exploited. Iron and Steel industries were built in the Ukraine. These extraction points were critical for tsarist growth at the beginning of the century, and repairing them and further development contributed to early Stalinist growth. During the 5YP, the industry was also developed in the places further inland that had become industry hubs out of necessity during WWI. These established regional innovation systems and industrial fabrics are still relevant to today's Russian NIS in Siberia, the Urals, and Central Asia.

Despite early success, by the Summer of 1930, it became apparent that the quotas and goals of the 5YP were not going to be achieved. The goals of this first 5YP were not achieved until after WWII. In conclusion, the first 5YP did not achieve the over-ambitious goals of the Soviet regime. Still, it was very positive for the NIS, with a doubling of the industrial workforce in just 4 years (Davies, 1998) and establishing an industry basis through the investment in capital goods that would be leveraged in successive years.

The second 5YP started officially in 1933 and lasted until 1937, a period of political unrest in Europe and Asia. Stalin's fear of an invasion conditioned the 5YP. Having learned from the previous plan, the second 5YP was less ambitious and leveraged the existing infrastructure. Collectivisation was abandoned after the famine of 1933, and agriculture quickly recovered. By 1935, rationing was abandoned, and the country had a feeling of abundance. GNP increased 55% during this 5YP (Davies). The 30s showed a 10-15% annual growth of the Soviet economy, but not enough time passed for it to establish and be robust enough to withstand another war.

Through education and modernisation, the cultural revolution enforced education countrywide and taught in Russian in an attempt to homogenise the population. Education was very important during the whole Soviet period, and this started during the Stalin era when compulsory education slowly increased in the number of compulsory years. This established a great education basis for the population, greatly increasing the NIS's knowledge stock. Schooling was so critical to the Soviet idea that even during the war, 35 million schooled children were in the country. This was a 5-time increase from the 7 million in 1928 (Davies, 1998) at the beginning of the first 5YP. Adult literacy also increased significantly through education programs for adults, and it increased from a 51% literacy rate to an 81% literacy rate in the same period (Davies, 1998)

As international tensions rose with the Eastern and Western borders compromised, Russian governance responded by diverting resources to the military industry. An emphasis was placed on the new industrialisation of the military complex to modernise weapons and their production process. This was the behaviour of most of Europe in the period that saw war as inevitable, with the German rearmament and the breaking of the Versailles treaty.



In 1938, a **third 5YP** was started, but it was abruptly stopped in 1941 after three and a half years with the **German invasion of Russia**. The main focus of this 5YP was to prepare for war, and resources were allocated to the military and taken away from other industries. The armed forces increased from 1.5 million to 5 million soldiers, and armaments production rose 250% (Davies, 1998). At the start of the war, the military industry was the single most grown industry by the 5YPs, and estimates put the increase at a 28 times increase (Davies, 1998). Diffusion happened to industries that split from the military, such as metallurgy, fuel, machinery, and chemicals, but there was very little spillover elsewhere. Spillover and the accumulation of knowledge were not measurable outputs achieved by central planning, so there was little incentive for it.

German industrialisation outperformed Europe in the previous and the first years of the war until the war caused severe shortages and could not sustain the need for armament replacement. The industrial and innovative superiority in the armaments industry allowed Germany to surprise all of Europe and wage WWII. The other European countries already had an important arsenal and industrial fabric because, as winners in WWI, they had not had to scale down their army and military industries. In the autumn of 1939, after a policy of appeasement that allowed early German strategy and protection of key industries like steel in the Ruhr Valley, Britain and France declared war on Nazi Germany after the invasion of Poland. Russia did not declare war at this time as it had signed a non-aggression pact with Germany the previous year.

By 1941 Nazi Germany invaded Russia, the efforts of the 5YP proved insufficient, and Germany quickly invaded Russian territory. This is a clear failure of Soviet governance and the NIS, which failed to support a war economy against a far superior NIS. War came at a huge human and infrastructural cost to Soviet Russia, and a lot of the labour that was supposed to be working in industry was conscripted. By 1942, the number of soldiers in the Red Army doubled, and during the war, estimates of at least 16 or 17 million were forcibly called to war. The occupied areas were critical agriculturally and industrially. Widespread famines occurred that year, and the government had no other alternative to return to rationing. Much of the industry pivoted towards the war effort, especially for the consumer goods industry. This halted the development of a NIS that was already behind the rest of the world just when it was starting to flourish.

The war was, however, different for the two countries that came out on top after the war. The USA and Britain saw no land fighting at home and were able to keep domestic industries going during most of the war. Two war government labs stand out: Bletchley Park in the UK and Los Alamos in the USA. Because of the considerable security allowed by their geography, both countries could choose to spare scientists from conscription and use R&D and the NIS to improve the odds of winning the war. Germany experienced similar security because of military superiority in the early years of the war, allowing her to spare scientists and focus on innovation to win the war.

The war brought lots of innovation aimed at obtaining competitive advantage over the enemy. Innovation was attempted by all war factions, but the Soviets were the least successful. Computers and electronics were improved and made ready for the war, which saw huge innovations in these industries. There were great improvements in aviation with the invention of jet engines and rockets, which would later make the space race between the USSR and the USA possible. Nuclear technology was harnessed for the creation of the atomic bomb and research it would develop into the nuclear arms race. Still, it would also have many civilian and industrial applications that shaped the century's second half.



The Russians played an important role within the Allied forces to defeat the Nazis as they fought back through the Eastern Front of WWII and into Berlin, they received American supplies and investment, but they mostly fought the invasion alone. This meant that Russian territories were devastated by the land war, and estimates put the total casualties at around 28 million, with one-third of the young males killed (Davies, 1998). If we add this to the casualties of WWI and the Civil War, the first half of the 20th century was a catastrophe for Russian demographics.

After the war, the conversion of the armaments industry back to consumer civilian production was slow, and the armament industry kept being critical because of the fear of Allied invasion and the start of the Cold War. Stalin tried to return to the economic policies of the first 5YP, which positively affected industry. This focus on quickly recovering the industry meant that agriculture took longer than the rest. The early years after the war came with huge famines in the Western territories of the Soviet Union, especially in Ukraine.

To combat this, Stalin incentivised a modernisation of agriculture through the building of tractors, which by 1950 were being again produced at the same rate as before the war (Davies). A lack of foreign investment opened again a gap between Russia and other countries that had seen the worst of the war, like Japan or Germany, which quickly recovered and started to compete with the innovation superpowers.

The end of the war saw Russia getting back most of the territories lost after WWI, like the Baltic States, and gaining influence in many others, where communist regimes governed like Bulgaria, Romania, Mongolia or Yugoslavia. It also established communist puppet states in Poland, Czechoslovakia and East Germany. Resource gains were introduced into the Soviet agricultural supply system. This was especially problematic as the Soviets extracted agricultural resources from these countries to feed their citizens, often leading to shortages and famines in the occupied countries.

The military still dictated much economic and innovation policy as WWII transitioned into the Cold War. The first order of business of the post-war Russian NIS was to replicate the atomic bomb, which was accomplished by 1949 to level with the USA in military power. The quick response was more a work of efficient espionage than a successful innovation out of the Russian NIS; however, a nuclear industry was quickly established, and innovation developed from the knowledge obtained through espionage.

By 1950, education recovered completely, and compulsory schooling was elevated from 7 years to 10 years. Higher education boomed after the war; by 1950, 177000 new citizens had graduated from a higher education institution. This was a 50% increase from the best recorded pre-war year (Davies, 1998). The 1940s were critical for higher education, and even with the war, the number of universities increased from around 120 to 400 by the end of the war. Most big cities in the Soviet Union now had a university that could serve the citizens. This created a good ecosystem for regional innovation systems focusing on the territorial strengths in many of the remote places of the Soviet Union.



Key Point

The main events of this period were the adoption of Communism and the Second World War. Communism shaped all areas of Russian life and brought the economic plans that controlled the NIS. The Second World War was the single most destructive event to the NIS in the period studied; however, it also conditioned the innovation that resulted in the following years.

4.2.4 Comparative Analysis Fourth Industrial Revolution 1950-1990

The introduction of mass production, radio, TV and consumer goods marks the fourth industrial revolution. The data for this period is less contested than in the previous period, but it is still based on estimates, and there is some disagreement between sources. During the period, the Soviet NIS reached its highest point and slowly broke down with all the Soviet institutions until the Union was dissolved. It is a period of great global instability, marked by proxy wars, but a period of fast-paced innovation, especially consumer innovation, as opposed to the focus on military innovation of the previous decades.

After the Allied victory in WWII, R&D gained enormous prestige and innovation investment was popularised amongst industrialised countries. Developing countries trying to catch up also tried establishing policies to replicate the weapons used in WWII. However, most of the major players that came on top after the war have remained innovation superpowers. R&D policies typically include investment in government labs and scientific institutions.

After the war, lots of countries tried to replicate the atomic bomb out of survival instinct. Very few have achieved this feat because of the high financial cost and complexity of the technology and infrastructure necessary to accomplish it, which most countries lack. Since the 1960s, international pressures and agreements have limited innovation in the nuclear weapons industry. The Soviets had their first nuclear bomb produced in 1949 and continued developing a nuclear arsenal throughout the Cold War. One of the only success stories of the Soviet NIS permeating knowledge from one industry to another was a major advancement for the world as Soviet scientists applied the knowledge obtained in the development of nuclear weapons to harness nuclear energy for electricity and be the first in the world to use nuclear energy peacefully in 1954. Arguably, the permeation happened within two sectors where the Soviet government invested while neglecting others. Still, this permeation proves the strength and growth of the Soviet NIS in the early 1950s.

During WWII, most of the industry was repurposed for war and moved inland to stay far away from the invading Nazi troops; this made industry reach cities inland that had never had an industrial fabric and that today still have conserved it. It helped expand the NISs and delocalise them from Moscow, St Petersburg and the Western border. By the 1950s, many factories were back to normal functioning, and consumer goods were again widely available to the population.

In 1953, Joseph Stalin died, and Nikita Khrushchev was named First Secretary of the Communist Party. Khrushchev wanted to break with his predecessor and started a process of “de-Stalinization”. He tried to move away from the totalitarian rule of the Stalinist administration and attempted a liberalisation of economy and politics. During his 11 years as the leader of the Soviet Union, there was a marked increase in foreign trade, especially with other communist nations.



Agriculture still represented most of the Soviet Union's GNP, and some innovations were made through Khrushchev's **Virgin Lands Initiative (1953)**, where non-agricultural lands in the Asian countries and the Eastern remote regions were made fertile to increase the yield. This initiative got 300,000 young Soviet workers to emigrate to the virgin regions to start a new life. The first year of the initiative, 1954, saw a great increase in yield and by 1960, the USSR had increased its farmland by 90% (Davies, 1998). This initiative successfully reduced the food shortages that had plagued the Soviet Union since its inception. It boosted the chemical industry through the production of 60 new fertiliser plants. By stabilising the food shortages, political stability and quality of life increased. By the 1970s, Russia's agricultural economy, which was chronically inefficient and incapable of reaching self-sufficiency, forced Russia to import food from the West in exchange for Petroleum and Natural gas.

The comparison with the USA during that period was constant, and there was a sense of pride in the domestic policies of the Khrushchev government. Throughout the Cold War, there was a need to build infrastructure for publicity stunts and to achieve victories in the proxy wars that the Americans and Soviets fought on foreign soil. This period saw many of these minor wars where both sides would support a side with investment and armaments, hoping that the side closer to their ideology would win and another country could be added to their sphere of influence. This period saw the Korean War (1950-53), the Vietnam War (1953-1975), and several bloody conflicts in Africa, Central and South America. This period also saw another direct confrontation between the USA and the USSR: the space race. The space race occurred as both powers competed to be the first to achieve milestones in space exploration.

Both military and space were areas of great interest for the USSR because much of the publicity extracted from both industries kept the person in power popular and boosted a spirit of patriotism. During the Cold War, many government R&D labs were set up for the development of military weapons like ICBMs and nuclear weapons. Many factories built armaments, military vehicles and aircraft that were then shipped to many of these proxy wars. Soviet military equipment had a very good reputation for reliability and quality. At the height of the Cold War, one-quarter of the country's industrial workers worked in the military sector, accounting for an estimated 20% of the country's GDP. The centrally planned and closed national innovation system provided little incentive to enterprises to diffuse new technologies from these sectors to other sectors (Freeman, 1987).

The Russians beat the USA to put an artificial satellite in orbit in 1957. This feat required government investment in the space industry as well as the knowledge of rocketry that the Germans had developed during WWII and that permeated Russia after WW2. The next big Russian feat was sending the first man into space in 1961. Both victories were heavily publicised in Soviet patriotic propaganda by the Khrushchev government. Secretly, they were aware there was still a considerable technological gap in nearly all other industries. The USA beat them with the Apollo moon landing in 1969 and established themselves as the leader in space exploration. The Apollo program permeated considerably better to other industries than the Soviet Space program, with knowledge from the Apollo missions used in the telecommunications sector, material science or computing. NASA established a program tasked with diffusing knowledge from the space industry into other industries.

The next American space victory was the global positioning race in the 1970s, in which the Americans beat the Soviets to develop GPS, and the Soviets had to innovate again in a reactionary manner by developing GLONASS. The USA launched the first GPS satellite in 1978, while the Soviets followed in 1982. The civil applications of GPS have permeated most modern



industries through navigation and logistics. GPS has been available in some manner for civil use since the 1980s; on the other hand, GLONASS was not public until the early 2000s. This has greatly impacted the NIS of all countries using GPS, improving communication and navigation and giving birth to a new mode of operating logistics. The Soviets and, later, the Russians could not leverage their innovation outside military applications until nearly 20 years later.

In the mid-60s, Khurushev was deposed, and Leonid Brezhnev became the General Secretary of the Communist Party. He was the leader of the Soviet Union from 1964 to 1982. After a couple of years of establishing his position, Brezhnev started a policy of *detente* in which tensions with the West were de-escalated. This reduced the state of alarm within the country and allowed some years of peace to divert investment from the military. The detente was broken when the **Afghanistan War (1979-1989)** broke out.

The 1960s ended with a high proportion of investment in the capital goods industry and defence. The iron and steel factories in the Urals set the basis for a healthy industry that could grow exponentially. However, as discussed, interindustry diffusion outside the priority sectors was minimal. Homogenising all products within the state allowed the government to work economies of scale to make up for some of the inefficiencies. However, central planning and homogenisation meant that any error was a costly nationwide error that was implemented all over the state. The success indicators for innovation were not aligned with a strong NIS, and investment was mostly myopic, not focusing on the knowledge accumulation intangibles.

The early policy of detente allowed foreign trade with the West, which, in essence, meant that imports of superior products were possible. This allowed the NIS access to the Western stock of knowledge, which improved the system considerably and translated to early growth. The first half of the Brezhnev administration saw improved living conditions and reduced the population below the poverty line (Bunce, 2009). This was true not only for Russia but also, for the first time, for the FSU Republics. The new relationships with the West evolved into a reduction of nuclear arsenals and agreements on the control of nuclear weapons that not only established Russia and the USA as the leading nuclear superpowers but also allowed the Brezhnev administration to divert resources from the defence sector. After the Soviet invasion of Afghanistan, relationships with the West broke down, slowing the influx of knowledge from the West and halting trade with the Western markets. Russia had to focus again on defence, which halted the scientific-technical revolution starting in the country (Bunce).

Early on, Brezhnev used some of this newfound capital to focus on the country's stability, and recognising that a strong agricultural sector was the way to avoid supply-related instability and conflict, started a modernisation of agriculture that had consequences on much of the Russian economy. The communist bloc was planned as a whole, abandoning the regionality of the Khrushchev administration. The countries were divided and specialised according to their industry strengths, some acting as bread baskets and others focusing on goods and machinery. This decision still resonates within today's NIS in the FSU republics, where most countries with an established machinery and goods industry in this period still have a considerable industry, and the bread basket countries are still mostly agricultural. This allowed some countries to become prosperous and condemned countries like the Central Asian Republics to depend on foreign aid and to have limited agricultural-based economies.

By the 1970s, the communist bloc was a disadvantage for Russia more than an advantage. Maintaining all the republics, including Cuba, Mongolia, and Vietnam, became a burden to the Russian finances, and they had to invest large amounts of capital in these territories. To finance



this, Russia fell into a debt trap in which money was borrowed from foreign investors, and when it came time to pay back the debt, more debt was incurred to pay it. By the end of Brezhnev's administration, growth was diminishing, and a global depression hit the country. (Bunce, 2009). OPEC expanded oil production in the 1980s, and the price of oil fell from 75\$ a barrel to 20\$ a barrel. At this time, the USSR was the world's largest producer of oil and gas, most of which was extracted from the gigantic fields in Western Siberia, which still produce most of the country's output today. By the late 1980s, oil and gas had provided 60% of Russia's hard currency earnings (Goldman, 2008).

During this period, the Soviet Union was one of the most educated societies on earth, with virtually all the population being literate. The main objective of the education system was to raise loyal followers of the Soviet state, and the quality of education sometimes took second place in this. The Soviet Union had universal education and reached 100% literacy. Many universities were built in remote places, bringing knowledge to the country and creating technology hubs around universities in cities in all provinces. Academic work was incentivised and respected within the USSR. Education numbers rose consistently throughout the period, with higher education rising at around 100 institutions per decade, going from 400 in the 1950s to around 800 in the 1990s. Even with this increase, there was a clear lag with the global powers like the USA, where by the end of the period, there was a 28% college-educated population while a bit over half, 16%, in the USSR.

In 1982, Brezhnev died, and a series of short-lived presidents with poor health continued with very short administrations of close to 2 years each; these were the **Andropov (1982-1984)** and the **Chernenko (1984-1985)** administrations. Both administrations tried to introduce quick reforms into the Soviet economy to return to the better years after the war, where the gap with the global superpowers was slower. However, the instability that two quick successive governments introduced into the Soviet Union proved fatal for its continuation. Andropov tried to tackle inefficiencies in the Soviet economy, one of its major weaknesses. The policies were successful early on, with industrial output showing rapid growth in his first year in office. After Andropov's death, Chernenko was a politician of Brezhnev's "old guard" and was appointed as a return.

After the short run of both presidents due to illness, a younger candidate was chosen, Mikhail Gorbachev, who was the last leader of the Soviet Union. He tried to return prosperity through three key policies: The first was *glasnost*, a policy of transparency in government to appease the grand corruption within the communist party and in all levels of management within the country. The second policy was *perestroika*, a restructuring of the economic system. The final policy was *uskoreníe* or acceleration. Like all leaders before him, Gorbachev wanted to close the technological, military and economic gap with the world powers.

The first policy to be implemented was *uskoreníe*, which targeted heavy industry and those industries where traditionally Russia had excelled. It was focused on closing the gap with foreign powers by modernising industry. A considerable investment was made in new technology to boost the efficiency of an industry that was far from its potential. The investment, however, did not translate to increased profit or productivity. Management of the industries lacked expertise, and much of the new equipment that had been invested in was left unused. The policy was ultimately negative for industry and undermined the confidence in the government.

Glasnost was a policy of transparency aimed at increasing internal debate and freedom of speech. This policy was aimed at the Soviet institutions, which were often impediments to

developing a strong NIS. During the duration of the policy, literature was decensored, and Stalin's crimes were made public. The process also lightened the bureaucratic process for importing and exporting, which increased foreign trade and the permeation of ideas from the West again. Still, it also created doubts about the communist system within the country that would eventually develop into the dissolution of the Soviet Union.

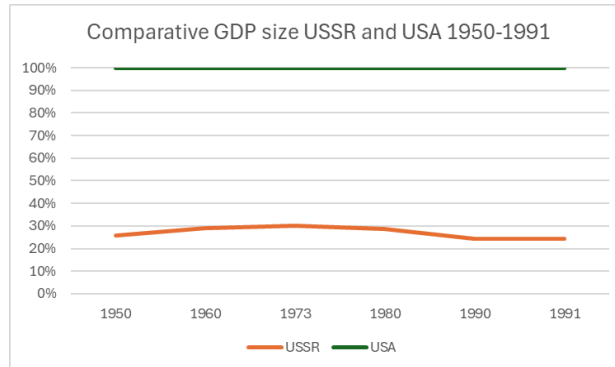
Perestroika was an attempt to bring life to an economy with declining growth. A market economy was introduced, and a liberalisation of the economy started. The Russian system had no infrastructure to support a market economy, resulting in inflation and goods shortages. Factories lacked competitiveness, and managers did not know how to navigate a market economy, leading to significant industrial productivity declines. Critical industries like energy and food were especially vulnerable to the change. Perestroika revealed a truth that would become apparent once the economy was completely liberalised: some industries in the Soviet Union could not survive without government subsidies and could not compete with their foreign counterparts. Industries were forced to modernise and adapt or close down. Eventually, Russia's historically strong sectors like energy, extraction, and defence bounced back.

The Soviet innovation system is often characterised as flawed, inefficient and corrupt. However, it is often overlooked that an excellent system of hundreds of universities was set up nationwide, which still exists today and allows production quality and a skilled workforce. Government research labs were set up in critical industries like oil and gas. In sectors where Russia is a global leader in innovation, many of the developed processes are still used today. By the end of the period, Russia had 1 million scientists (technically skilled workers), representing around 18% of the world's total (Blinnikov, 2011). This clearly shows that the problem was not infrastructural or was caused by a lack of resources. The truth is, however, that the NIS was very slow to innovate and that the quality of the innovations was subpar, especially when the competition was not only the USA and the UK any more but new players were out-innovating the Russians like Germany or Japan.

Innovation was not diffused or assimilated between industries. Still, it was sometimes not even done within the same industry in two different locations in the country, even when the means to assimilate and improve were available. For example, in the 1970s, the Soviet Union was the world's leading metal extractor, leading the charts in producing iron ore, steel and pig iron. The extraction process is energy-intensive, and it is often tried to innovate in the direction of efficiency. The electric furnace extraction method was invented in Russia in the early 20th century. Its use is, however, tied to the need for an electrical infrastructure and a high initial cost. The Russians could only afford a less efficient method, severely compromising yield. Russia was unable to capitalise on the output of its system because although some of the nodes of the system were very capable and innovative, the links between nodes were not there.

Regarding innovation, there is no question that the USA and Europe were more successful than the FSU republics. The Russian NIS tried to catch up for most of the Soviet period, focusing on some industries where governance felt it was critical to match the other global powers while neglecting others. The truth is that GDP growth was very similar, with Russia having a GDP of roughly 30% of the USA for the whole Soviet period after WWII, with the only ones showing outlier growth being Germany and Japan. By the end of the period and near the fall of the USSR, Russian growth started to stagnate, and internal tensions became unsustainable.

Figure 10: Comparative GDP size of the USSR and the USA



Source: Rosefiende

Key Point

The most influential events of this period on the NIS were the Cold War, which brought the Space and Nuclear arms Races and the Fall of the Soviet Union, which brought free markets, Western influence and the territorial division in FSU republics.

4.2.5 Comparative Analysis Fifth Industrial Revolution 1990-Present

The widespread adoption of microelectronics, computers and the internet has marked the fifth wave of industrial innovation. After the fall of the Iron Curtain, the reliability of Russian data increased considerably, and its inclusion in global innovation rankings allowed a switch to a reliable hybrid quantitative and qualitative analysis. By the 1990s, similar to the 1910s, the civil unrest became unsustainable, and governance collapsed. In 1991, the Soviet Union dissolved and was divided into 16 FSU Republics. This was a critical point for the NIS, where the government changed the economic policy and brought new ideas and market forms, opening the borders again to the foreign stock of knowledge. The Russians soon discovered once again that there was a technical gap.

After the collapse of the Soviet Union, Boris Yeltsin was made president, and his first order of business was to dismantle the Soviet legacy and establish the new Russian Federation. The NIS was no exception. Yeltsin and his government adopted “shock therapy” to transition a country centrally planned for 70 years to a market-based economy. The extractive industries, the backbone of the Russian economy and on which it had proved overdependent, were privatised. Brezhnev accused Gorbachev’s perestroika of being a “*half measure*” and wanted to go further.

The rapid transition allowed the remnant corruption of the Soviet Union to affect the privatisation. The powerful within the Soviet organism were the ones who became major shareholders of the newly privatised industries. This gave rise to the Russian oligarch, who plays a key part in today’s economy and governance. These men used their connections during the Soviet period to leverage huge wealth and control industry, especially in the energy sector. The oligarchy resulted from Yeltsin’s *perekhod* policy, which he intended to facilitate a swift transition from communism to free enterprise. Russia was experiencing a Westernization of its markets, but its governance stayed authoritarian. The Soviet system had no experience with the free market, and the inefficiencies of the Soviet Union that had been combated with price fixing



rose to the surface. Now that the import of Western goods was possible, the subpar quality of Russian manufactures was apparent.

Heavy manufacturing, a staple of the Soviet economy, especially under Stalin, fell by 85% in the first years of the Yeltsin period (Blinnikov, 2011). For example, the aerospace industry that under Soviet governance flourished and was one of the spearheads of the NISs struggled and slowly closed. Nowadays, all domestic commercial airliners in Russia operate with imported Boeing and Airbus aircraft. These two companies are huge players in the NISs of the USA and France, respectively, where they have a considerable spillover into other industries resulting from their extensive R&D. A similar thing has happened with the automotive industry.

By the end of the millennium and with the Russian Ruble crisis, science got investment severely cut. With less financial support and the fact that working in R&D was less attractive than during the Soviet period, emigrating became popular amongst Russian scientists. Between the fall of the Soviet Union and the Putin election, at least 500000 Russian researchers and scientists fled the country. This created irreparable damage to the NIS. It subsidised all of the foreign NISs that competed at the time and gave away a knowledge stock worth over a few billion dollars for free to Western Europe and the USA. A very revealing statistic of research funding in post-Soviet Russia is the budget that the Russian Academy of Science reported for 2005, which was just under \$500M, which is what an average university in the USA will have as its research budget. With this budget, the RAS had to fund 400 labs.

In 2001, Vladimir Putin rose to power after Yeltsin renounced the position. He has been the autocrat who has been ruling Russia since. Recently, a rule was passed that allowed him to be president until 2036 constitutionally.

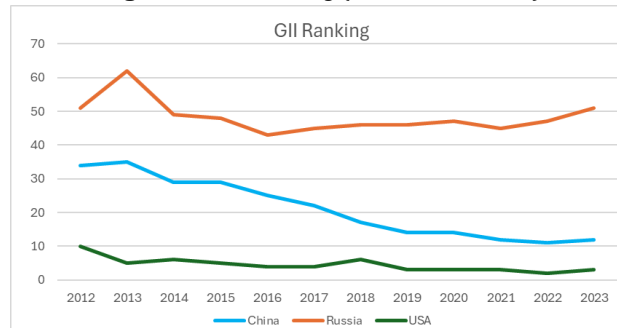
Slowly, like most things in Russia, the NIS has been left to age without real support or supervision since the government stopped planning the direction of every single industry. Since 2007, an attempt has been made to sustain and reuse the ageing Soviet labs. The government has introduced a new policy in which a budget is given to revitalise old research infrastructure, hoping that building on the existing system may leverage existing stock and links. This is a good change of policy from a Russian government that has always preferred to scrap everything from the previous period and start anew, discarding the old NIS and being quick to dismiss the legacy of knowledge accumulation. Since 2010, there has been a return to state-funded research universities and technoparks to incentivise and ease R&D.

The last 15 years have been tumultuous in Russia, with a return to expansionist policies, trying to expand its borders through military action. After a short political tension buildup in 2014, Russia annexed the Crimean region using a combination of traditional military and cyber warfare. Quickly, regions of the Donbas were seized. This region was an important coal extraction point during the Soviet period, and it is also rich in metallurgy and oil. In 2021, Russia built up troops on its Eastern border and proceeded to invade Ukraine in an action that was condemned globally and that led to the start of a war that is still ongoing. It has severely damaged their international reputation, and sanctions have been imposed on Russian markets, limiting their trading partners and the permeation of knowledge again.

A GII data comparison with reliable data is available for this period. The countries chosen for comparison are the USA, as the global leader and military counterpart to Russia and China, as a member of BRICS that aims to take Russia's place in the world as a second global power with the

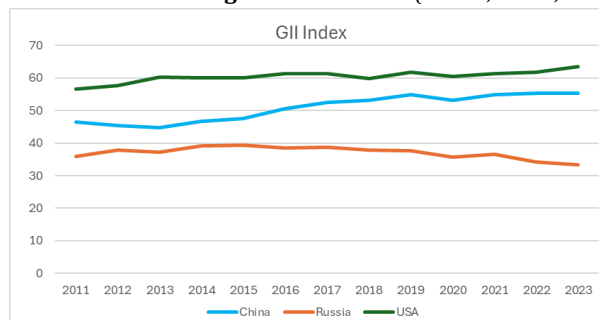
USA. Another interesting reason to choose these three countries is their extension as they all have big landmasses and access to many resources from that land.

Figure 11: GII Ranking (Russia, China, USA)



Source: GII Report (2012-2023)

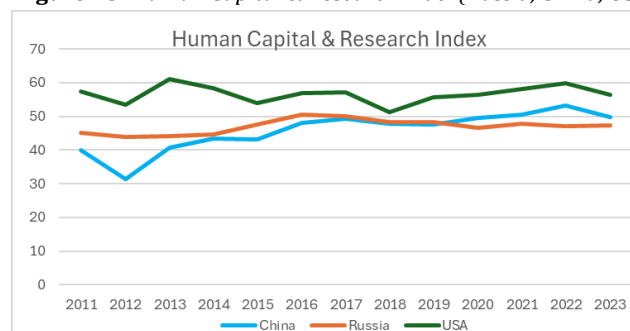
Figure 12: GII Index (Russia, China, USA)



Source: GII Report (2012-2023)

At the start of the period, the USA was barely in the top 10, not the innovation leader that may be expected. Russia and China were countries in the middle of the pack, with China being superior to Russia. Russia was far from the USA in terms of innovation, but it was relatively close to China. The next 13 years have seen China develop into one of the innovation leaders. Meanwhile, Russia has maintained its position stable, with the index slightly decreasing since the start of the Ukrainian invasion. China has gained a place of global influence through innovation. China is developing a well-oiled NIS that has been building steadily since the 1990s and that has been given the time to mature. These innovation indexes result from years of development of innovation policies, institutions and R&D labs.

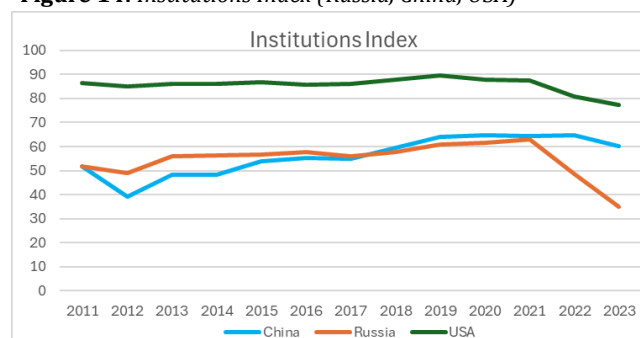
Figure 13: Human Capital & Research Index(Russia, China, USA)



Source: GII Report (2012-2023)

The only parameters in which Russia is comparable to the other two countries are human capital and research, which have not been affected by the invasion of Ukraine or the pandemic. The university system that the Soviet Union left behind has been maintained and developed in the last 30 years. There are many science and engineering graduates, with a long tradition. Russia is especially famous in computer science, and the government has recruited graduates for cyberwarfare. In this graph, the results of China's investment in universities can be appreciated, with a similar focus on STEM graduates and a formula close to the Soviet university system, where new universities are opened all around the country to form regional hubs. The American system has been very stable during this period, with the added advantage that the USA obtained many foreign students who excelled in their countries and were admitted into American universities, essentially integrating foreign talent into their NIS and taking it away from other countries.

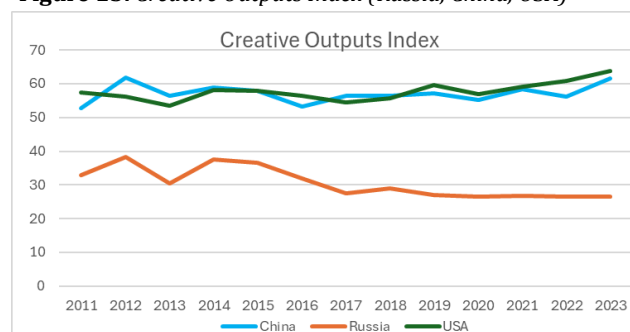
Figure 14: *Institutions Index (Russia, China, USA)*



Source: GII Report (2012-2023)

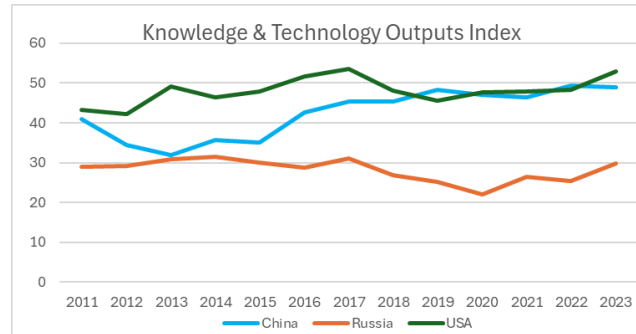
One of the main weaknesses of the Russian NIS in this period is its institutions, most of which are ageing and remain from the Soviet transition period. As we can see, they are comparable to Chinese institutions for most of the period. However, China has invested in policies to allow business, especially foreign business, and the promotion of entrepreneurship. Institutions have been severely affected since the invasion of Ukraine and the pandemic. The index has plummeted by around 30%, with the tendency to continue this year with the intensification of the war as sanctions intensify and the difficulty of doing business in the country.

Figure 15: *Creative Outputs Index (Russia, China, USA)*



Source: GII Report (2012-2023)

Figure 16: Knowledge & Technology Outputs Index (Russia, China, USA)



Source: GII Report (2012-2023)

There has been a big output gap between Russia and the other 2 countries. Since 2013, China's knowledge and technology output has been growing from the same starting point as Russia's and has reached the levels of American outputs while Russian outputs have slowly declined. China has been, in this period, the global leader in trademarks and the export of creative goods and is slowly also becoming a leader in online creativity. It has also grown in its patent strength and knowledge impact while still having some gap in its diffusion capacity.

Figure 17: GII Index Comparison Summary (Russia, China, USA)

Country	2012	2023
Russia	Middle of the pack, penalized because of institutions. Human capital & research as a major strength.	Trending towards losing innovation capacity. Further involution of institutions.
USA	Fall from the global innovation elite. Institutions as a major strength.	Return to leading global innovation. Slight deterioration of institutions. Slight increase in outputs.
China	Aspiring to become an important innovative global player. Penalized because of institutions and Human Capital & Research.	Getting closer to becoming an innovation leader. Institutional improvement with margin to improve further. Considerable improvement in Human Capital & Research.

4.2.6 Comparative Analysis Summary

The following table summarizes the main events in the study period and defines the short and long-term effects of the event on the NIS.

Figure 18. *Comparative analysis summary*

Event	Short-term Effect on NIS	Long-term Effect on NIS
Crimean War (1868)	<ul style="list-style-type: none"> - Destabilization of the economy - Sale of Alaska 	<ul style="list-style-type: none"> - Societal instability - End of the monarchy
Construction of the Trans-Siberian Railway (Late XIX century)	<ul style="list-style-type: none"> - Ease of transport and communication 	<ul style="list-style-type: none"> - Regionalisation of NIS away from the borders - Importance of the iron extraction industry
Russo-Japanese War (1904)	<ul style="list-style-type: none"> - Loss of popular confidence in the Tsar - Economic & human loss 	<ul style="list-style-type: none"> - Russian Civil War - Early modernisation of military industry.
WWI (1914)	<ul style="list-style-type: none"> - Economic & Human loss - Abdication of the Tsar - Russian Civil War - Loss of territory 	<ul style="list-style-type: none"> - Instauration of communism - Transformation of industry towards a military economy
Russian Civil War (1917)	<ul style="list-style-type: none"> - Human loss - War economy - Halt of industrial production - Lenin's NEP 	<ul style="list-style-type: none"> - Instauration of communism - Brain drain
Stalin's Win over Trotsky & First 2 5-year Plans (1924)	<ul style="list-style-type: none"> - Consecutive 5-year plans - Collectivisation 	<ul style="list-style-type: none"> - Importance of agricultural heavy industry - Development of the energy industry - Large industrial workforce - Education quality and quantity improvement
WW2 (1939)	<ul style="list-style-type: none"> - Large economic and human loss - Shift of focus towards the military industry 	<ul style="list-style-type: none"> - Cold War - Space race - Innovation spillover from military technology advancements - Development of RIS in remote locations
Space Race (Late 1950s and Early 1960s)	<ul style="list-style-type: none"> - Sputnik Launch - Focus on the aerospace 	<ul style="list-style-type: none"> - High-quality of technical education



	industry	<ul style="list-style-type: none">- Importance of the aerospace industry- GLONASS GPS
Khurushchev Appointment (1953)	<ul style="list-style-type: none">- Virgin Lands initiative- Destalinization	<ul style="list-style-type: none">- Desubication of young people to satellite states- Decentralization of higher education
Cold War <ul style="list-style-type: none">- Vietnam War- Afghanistan War	<ul style="list-style-type: none">- Creation of military R&D labs- Development of Glonass	<ul style="list-style-type: none">- Consolidation and modernization of the Russian military industry
Brezhnev Appointment (1964)	<ul style="list-style-type: none">- Spetialisation of Estern bloc- Increase of higher education institutions	<ul style="list-style-type: none">- Reduction of the nuclear arsenal- Main focus of FSU economies today- Quantity of higher education graduates dispersed around the NIS (especially technical degrees)
Gorbachev Appointment (1982) & Fall Of The Soviet Union (1991)	<ul style="list-style-type: none">- Rise of Oligarchs- Market economy- Ruble Crisis- Reduction of science funding- Permeation of technology through the border	<ul style="list-style-type: none">- Few people control most of the NIS resources- Closing of industry- Brain drain
Putin Appointment (2001)	<ul style="list-style-type: none">- Attempts at state-funded redearch- Interruption due to military conflict	<ul style="list-style-type: none">- Focus turning tothe military industry

5. Conclusions

In this section, the study's conclusions will be presented using the previous sections to explain how history has conditioned the Russian NIS and the reasons for this. Russian society has been through hardship and change in the last 150 years, as has the Russian NIS. The constant changes in governance have tried to look as different as they have been capable of looking from the previous iteration. This has mainly been to hide that the thing that has remained constant below all the superficial change has been a totalitarian leader in the seat of power.

Russia's NIS at the beginning of the study period is slow to accumulate or diffuse knowledge. Other competing NISs have better infrastructure, human capital and institutional support. The main advantage is an untapped investment fund of natural resources that is starting to get used for development. Compared to the rest of the NISs of the global powers, it has a lag of about half a century. Their objective is to catch up with the time-developed European systems as quickly as possible, finding ways to bypass the organic growth of these established systems with artificial means of system creation.

During the rail and steel Schumpeterian wave, incompetent governance punished the Russian NIS, and the disregard for foreign ideas and a forward escape through the traditional Romanov way of appeasing the population prevented the stable development of the system. Russification developed into an over-dependence on the domestic market that is still present in today's NIS. Conservative policies and the difficult access to general education made the incentive for innovation small. The increase in infrastructure and the stability of the Ruble improved the NIS considerably. Still, it was a marginally smaller development than the countries with which Russia wanted to compete by size and resources. Given the global innovation wave, Russia had the resources to innovate at the same level as the global leaders in this period. Still, it lacked the know-how or institutional stability to reach its potential.

In the third Schumpeterian wave, the Russian NIS experienced a change of governance; however, institutionally, very little changed, and it remained one of the main weaknesses of the NIS. The Russian NIS is a slave of tradition, and it defaults to inefficiency and funding the military to the detriment of everything else. A lack of patience with the NIS and a myopic bias for tangible output is ingrained in the Russian tradition and will constantly prevent the NIS from developing organically. The wars in this period severely damaged the infrastructure and demographics of the NIS and further widened the gap with the leading global NISs. The wars further compromised the ability of the NIS to develop and improve organically, forcing it to be rebuilt from the ground 3 times in 50 years. In this period, the positive developments of the Russian NIS were the availability of education made possible and incentivised by the Soviet government, as well as the territorial expansion, which brought some foreign know-how. The period shows an increase in human capital through this incentivisation of education, coupled with infrastructure in the form of new universities and schools—much of the infrastructure, which is one of the present NIS assets, dates from this period.

The fourth Schumpeterian period is one of the most densely innovative periods in global history, and the Russian NIS developed to compete in space and military with the USA but neglected to develop in all other areas. Institutional support for the NIS improved with the policies of destalinisation and increased freedom of speech. However, institutions changed constantly, and new policies were introduced, not letting the previous one develop completely, which made business and innovation difficult.



Infrastructure was developed to support the growing NIS, and factories and universities were built. In this area, there was also a bias towards space and the military and a neglect of all other areas of innovation. During this period, Russia established itself as a global power. However, the NIS developed slower than the American and even slower than the Japanese or German systems, which developed organically but quickly and established themselves as global innovators. Because of the support of these institutions, human capital and research peaked. After the fall of the USSR, most of this human capital fled. Still, the quality of the institutions allowed the replenishment of human capital with new graduates in the past decade.

These previous waves have certainly influenced the NIS's behaviour and development during the current innovation cycle, which has run parallel to the Putin administration, not only as the starting point of the NIS at the beginning of the cycle, which puts it at a disadvantage with global NISs but because of a legacy of innovative tradition that is ingrained in Russia's innovative DNA.

Freeman (1987) values a laissez-faire policy for R&D, a policy embodied in the USA's NIS from its foundation with figures like Benjamin Franklin. Over 150 years of autocratic rule in Russia, orders from the single source of governance to rush to innovate have been explored in this work, often changing the direction completely in sequential orders. The nature of autocracy and innovation to be reactionary and myopic, always being a follower of development abroad, has severely hindered the development of a stable and sustainable NIS. There has been very little laissez-faire and organic formation of a system and many orders bypassing the natural formation, expecting a quantifiable output, and ignoring the intangibles.

The NIS has been affected by these superficial changes that have tried to address the perceived weaknesses that align with the ideology in power. The biggest weakness of the NIS has always been the governance strand of the helix. There is no incentive for autocrats to address themselves as an institution because of the lack of competition. Furthermore, autocrats must show that their policies are correct to consolidate power and break away from their predecessors. This means that the NIS has had little time to grow and develop before a complete reorganisation occurs, wasting much of the knowledge accumulated in the previous iteration. This is not exclusive to totalitarian governments; however, in multiparty states, when there is a party change, the new governing party will try to install its policies and break with its predecessors. The difference with a totalitarian state is that the other strands of the helix are independent of the government and can keep developing despite the effect of the change with continuous growth. That change will rarely be complete and immediate. There is a smaller need for power consolidation when the legitimacy of your position resides in a democratic election. From this, one may argue that historical change has affected the Russian NIS at each turn but that the autocratic continuity has conditioned it the most negatively.

The constant promotion of isolationist policies has meant that the diffusion of foreign knowledge has been slow, coupled with the distance from the innovation hubs and the impermeability of the Russian border to foreign innovation. The many forms of government and the many invasions that Russia has suffered make the government and society untrusting of all border nations, and this is a difficult, self-imposed barrier to diffusion to overcome. Isolationism is not bad, and other countries like the USA have had similar policies during this period, which have brought positive results. However, these policies in Russia have translated into an overdependence on the domestic market. The Russian domestic market is one of the strengths of the NIS, according to the GII report. Still, over-dependence on a single market and one so tied to the NIS makes the situation delicate and over-reliant on prosperity. One of Nelson's



commonalities of a successful NIS is a good set of domestic customers coupled with exporting to avoid total dependency. This is where the USA and Russia differ.

Russia shares two main advantages with the USA: abundant land and resources. However, the distance of the USA from the centres of conflict and the apparent security of being separated from Europe by the Ocean has meant that the USA has exploited its land and home market in a way Russia hasn't been able to compete with. Geography and the successive wars in Europe have conditioned the Russian NIS negatively time after time through demographic catastrophe and infrastructure loss. The need to rebuild after every single war and the loss of knowledge stock that has come with each war has put Russia at a disadvantage after every major conflict it has participated in the period studied independently of military success. Wars have proved to be major leverage points of an innovation system, capable of bringing on a new wave of industrial innovation or sinking a NIS. In the aggregate, war has always conditioned the Russian NIS negatively. Although some positive changes have emerged from war innovations, its price has been steep. Apart from the mentioned human and infrastructural costs, the focus on military innovation from constant conflict has difficult diffusion of knowledge to other industries and the neglect of the civilian sectors that have been critical in developing the most successful NISs after WWII.

It is this military tradition that has conditioned one of Russia's strengths. The military tradition in higher education that started in Imperial Russia has developed with the modernisation of warfare and has put Russian engineers and physics at the forefront of innovation. Russian universities are prestigious in these areas, often linked to the defence industry. Russia has slowly developed an army of computer scientists capable of waging war from behind a computer. This has been seen during the current Ukrainian war. A combination of tradition and government incentives have conditioned the NIS to create an abundance of scientists and engineers but a lack of graduates elsewhere, knowledge that is also needed to support innovation. Furthermore, Russia has difficulty diffusing knowledge from the defence sector to other industries, and the abundant knowledge stock of high quality that comes from tradition and organic growth falls short of its potential as the system cannot leverage it as a whole.

Another commonality in Russia over the last 150 years has been a varying degree of censorship and prohibition of free speech and press. Barriers to expression, especially to foreign knowledge, have harmed the NIS severely compared with neighbouring countries where knowledge was shared and improved at the borders. The rule of law has been and still is one of the main weaknesses of the Russian institution.

The future of Russia is uncertain; countries like Finland, Poland and Slovakia depend entirely on Russian natural gas supplies for heat in winter and Austria and Germany depend to a lesser extent, sourcing 30% to 50% of their natural gas consumption from the Russian gaseous. This means that there is no incentive from Europe to start a war with Russia, which would have terrible, energetic consequences for these countries. Therefore, it is possible that the war will continue and that it may take some time to see a democratic government in Russia if it ever happens. After Putin, everything would point to another authoritarian leader taking his place and control of the NIS.

The NIS will continue to suffer because of the war and will keep declining slowly, held up by the existing infrastructure, the domestic market and the resource richness that Russia has. It will oscillate in the middle of the GII table without being able to reach its full potential in the way that China is aiming to achieve.



Without a complete institutional change that has time to establish and develop, the NIS will never be able to establish robust roots that allow it to overcome hardship and survive the change in the way the American system can. Every time change happens, the NIS is uprooted and modified, defaulting to traditional industries like extraction and defence. Change should come with an increase in the value of institutions and an opening of borders to let knowledge diffuse from the West easily and uninterrupted. Without a conscious break from NIS idiosyncrasies and an intentional investment elsewhere, these industries will remain the main sectors that benefit from the outputs of the NIS, while the other industries lack resources.

Finally, the study has found several limitations in its development. They are mainly of two types: statistical and analytical. The first type concerns the reliability of the historical statistics used for a considerable analysis period. Many statistics before the 1990s were doctored by the agent to measure them, sometimes for political or military reasons and others because of the difficulty of collecting numbers. Statistics are often inconsistent or incomplete, which has made it challenging to analyse development concretely. The analytical limitation comes from the interpretation of how events impacted the NIS, which, while the historical context may correlate strongly with the NIS's development or with direct innovation outputs, proving direct causality is challenging and may overlook other important factors that may be equally contributing to changes in the system. The regional disparity is another analytical limitation of the analysis mentioned in the study but is outside of the scope. Russia is a massive country with very differentiated regions, and modelling the NIS as the sum of the whole country may contribute to overlooking aspects of the development of the regional innovation system.



6. Sources

- BERGEK ET AL. (2008), "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis". *Research Policy* 37 407-429
- BLINNIKOV M. (2011), *A Geography of Russia and Its Neighbours*. United States: Guilford
- BUNCE V. (2009), "The Political Economy of the Brezhnev Era: The Rise and Fall of Corporatism". *British Journal of Political Science*, Volume 13, Issue 2, April 1983, pp. 129 - 158
- DAVIES, R.W. (1998), *Soviet economic development from Lenin to Khrushchev*. United States: Cambridge
- EKTOWITZ & LEYDESDORF (1998), "The Triple Helix of Innovation". *Science and Public Policy* · January 1998
- GADDIS, JOHN LEWIS, *The Cold War* .
- FREEMAN C.(1997), *The Economics of Industrial Innovation*. United, States: MIT Press
- LIST F. (1885), *The National System of Political Economy*. Internet Archive
- LUNDVALL B., CHAMINADE C, HANEEF S. (2018), *Advanced Introduction to National Innovation Systems*. UK: Edward Elgar
- NELSON, R. (1993), *National Innovation Systems: A Comparative Analysis*. United States: Oxford
- PATEL & PAVITT (1994), "National Innovation Systems: Why They Are Important, And How They Might Be Measured And Compared". *Economics of Innovation and New Technology*, 3:1, 77-95
- MADARIAGA, I.(1996), *Catherine The Great, A Short Story*. United States: Yale
- MEADOWS, D.(2008) *Thinking in Systems: A Primer*. United States: Eathscan
- ROSEFIELDE (2007), *The Russian economy: from Lenin to Putin*. UK: Blackwell
- POMERANZ W. (2019), *Law and the Russian State*. United States: Bloomsbury
- SCHUMPTER J (2003)., *Capitalism, Socialism and Democracy*. United States: Taylor and Francis
- SEBAG-MONTEFIORE S. (2015), *The Romanovs*. United States, Penguin
- WIPO. *GII Reports 2011-2023*
<<https://www.wipo.int/en/web/global-innovation-index>>



Annex 1: Russian Geography

A.1 Russian Geography

Russia is the largest country in the world by landmass, nearly doubling the following country. It spans 11 time zones, stretching from Eastern Europe to the Pacific Ocean, occupying the Northern part of the Eurasian landmass. It borders 14 countries and has maritime borders with two more (Blinnikov, 2011). It is rich in natural resources, such as energy, petroleum, natural gas, coal, and minerals like steel or nickel. It is a permanent member of the UN Security Council with veto powers, part of the Commonwealth of Independent States formed by the FSU Republics, and part of BRICS, G20, APEC and OPEC+ (Blinnikov, 2011).

A.1.1 Central Okrug

The Central Federal District is the country's administrative hub, where Moscow, the capital, is found. It is located in the European West of the Country and borders Ukraine and Belarus. Economically, it is the most important oblast, contributing one-third of Russia's GDP. It is connected by road and rail and has several international airports. It has been Russia's university and research hub for over two centuries, especially in the capital.

A.1.2 Northwest Okrug

The Northwest Oblast is located in the Northwestern part of European Russia, above the Central Oblast, bordering the Baltic Sea. The capital city is St. Petersburg, an important economic and cultural hub with a rich history that served as the state capital until the Bolshevik revolution in 1917. Another important hub is the city of Kaliningrad, geographically excluded from Russia and bordering Poland and Lithuania. This city is a port city to the Baltic Sea, making it a strategic point for Russia's political and economic interests.

A.1.3 Southern Federal Okrug & North Caucasian Okrug

This region, found South of the Central district and containing two districts, is important because the delta of the Volga River and the Caucasus mountains are found here. It borders Ukraine in the East and Kazakhstan in the West. It has ports to the Caspian, Black and Azov seas.

A.1.4 Volga Okrug

The Volga River watered the Volga region, which offers a flow of goods and information. It is one of the rivers most used worldwide for freight shipping. Apart from the river, the region is well connected with road and rail connections and international airports in the three major cities. The region has diverse economic activities with a lot of heavy industry, space industry, automotive and chemical. There are extensive oil fields and refineries and important coal and timber activity.



A.1.5 Ural Okrug

The Ural region is found in the central part of Russia, spanning the Ural mountains. The region is rich in mineral and energetic resources, and its main industries are metallurgy, fossil fuels and machinery. 19% of Russia's industrial output comes from this region, with the manufacturing of heavy machinery and cars being critical economic assets. In the 1960s, gas fields were discovered, developed in the 1970s, and are still active today.

A.1.6 Siberian Okrug

Siberia is one of the largest districts in Russia. Its extension is more significant than the EU, but it has a population of only 20 million, which is slowly declining. It is very rich in natural resources. 80% of the Russian coal industry is mined here, and there are also significant oil and gas reserves.

A.1.7 Far Eastern Okrug

This district is located in the Russian Pacific. Economically, it is not as critical as other districts. Still, it is of great military strategic importance as it borders China and North Korea on land and Japan and the USA on water. It is rich in mineral resources, with big oil deposits on the ocean floor and some precious metal and diamond extraction.

A.1.8 The Baltics

Estonia, Latvia and Lithuania are often described as “the least Russian of the Soviets” (Blinnikov, 2011); the 3 are EU members and members of NATO since 2004. They have a combined total population of 5 million. Since their independence from the SU, their trade has shifted to the West, and they have integrated politically, economically and culturally in the EU.

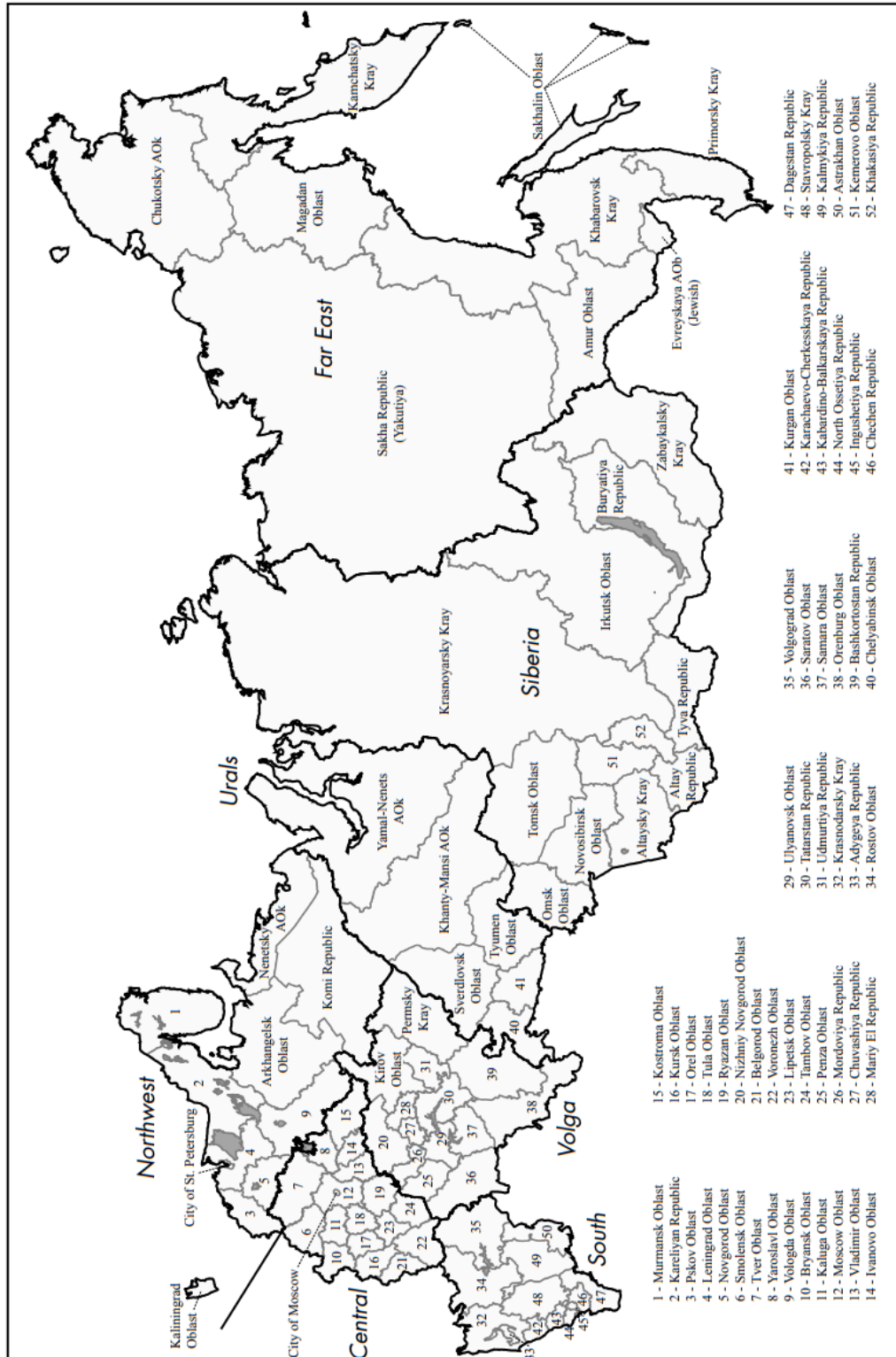
A.1.9 The Eastern Europeans

Ukraine, Belarus and Moldova are the Eastern European FSU republics. Ukraine is the largest of the 3 and heavily relies on agriculture, especially grain. It has faced economic challenges due to the current armed conflict with Russia. Belarus still has strong ties to Russia and, in many cases, acts as a transfer route between Europe and Russia. Moldova is a landlocked country that lies between Russia and Ukraine. It has rich and fertile soil and is known for agricultural exports.

A.1.10 The Central Asian Republics

The FSU Central Asian Republics are Kazakhstan, Tajikistan, Turkmenistan, Uzbekistan and Kyrgyzstan. All but Tajikistan are rich in natural resources, including gas and , and in many cases, both.

Figure 19. Russian Political Map



Source: Blinnikov, 2011