

**Natural science analogies in economic modelling: Vladimir
Bazarov's restauration process model**

Author:

Elizaveta Burina

Univeristy of Paris 1 – Panthéon-Sorbonne

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Preface

It is not rare in economic scientific investigation to borrow some methods, laws and models from other sciences through analogic reasoning. In the majority of cases economists are interested in the natural processes studied by physics, chemistry or biology “similar” to social processes. For example, the movement of a pendulum or string vibration could be considered having the same mechanics as business cycles. Thus, economists might use the findings of physicists to model business cycles in the image of pendulum dynamics. One very famous example of metaphorical presentation of economic system through physical notion, namely thermodynamics, is elaborated by Nicholas Goergescu-Roegan in his magnum opus *The Entropy Law and the Economic Process* [Goergescu-Roegan, 1971]. Apparently, the Romanian economist was neither the first nor the last one to use the laws of natural sciences, especially thermodynamic laws, in order to explain and model social phenomena. In the book *More Heat than Light. Economics as Social Physics, Physics as Nature's Economics*, first published in 1989, Philip Mirowski stated that it was natural for the economists to seek for analogies: “value as a concept is inseparable from our metaphorical understandings of motion and body. Metaphorical appropriations will continue under the banner of science” [Mirowski, 1991: 395]. Some attempts to describe economic system with the means of thermodynamics were made way before the publication of *The Entropy Law and the Economic Process*. Almost a semi centenary earlier, a Russian Soviet economist Vladimir Alexandrovich Bazarov proposed a model of social production process as a thermodynamic system. Together with that global model, developed for the social system as a whole, Bazarov elaborated numerous specific models for different economic phenomena, all of them based on physics and chemistry theories. Nowadays Russia does not remember Vladimir Bazarov and his theories though an expert on the early twentieth century Russian economic history, Alexander Erlich, in his definitive work *The Soviet Industrialization Debate: 1924-1928* called him “one of the intellectual lights of the Bolshevik movement” and “the leading non-partisan economist of Gosplan¹” [Erlich, 1960].

This work presents a detailed analysis of a restauration process model, developed by Vladimir Bazarov in his main theoretical work *Capitalist Cycles and the Restoration Process of the USSR Economy* [Bazarov, 1927]. To find an equation that would capture Soviet economy's recovery

¹ Gosplan (in Russian: *Госплан*) – the State Planning Commission of the Soviet Union, formed in 1921 as the agency responsible for central economic planning in the Soviet Union. It existed until the dissolution of the Soviet Union in 1991, and its staff were working on the development of the five-year plans. It was established at the initiative of Sovnarkom (Council of People's Commissars). Gosplan might be considered as an “extended version” of GOELRO – “State Commission for Electrification of Russia”. Indeed, it was the head of GOELRO Gleb Krzhizhanovsky who was tapped to lead Gosplan's work. In 1925 Gosplan started issuing the first annual economic plans, known as “Control Numbers”, and Vladimir Bazarov was the one actively involved in this work. The first five-year plan was introduced in 1928 (for years 1928-1932). This plan also was largely a result of Bazarov's theoretical and practical work.

after the revolution, the Civil War, and the World War I, Bazarov used the autocatalytic reaction equation, already existing in chemistry. His objective was to provide theoretical foundations for Gosplan's work in the early 1920s (Bazarov officially became one of Gosplan's economists in 1921) when the main challenge was creating the first five years plan, targeting the primordial steps of the incipient Soviet economy. Theoretical model, proposed by Bazarov, could be of interest for the modern economic science mainly because its elaboration drew heavily on analogies from a chemical process. Bazarov's methodology will be addressed in detail in the second part of the present work. However, it is necessary to specify what will be meant here by "analogy" since the very beginning. In Bazarov's sense, the processes are analogical in case "they have *identical* organizational linkages" and "the same *structure*" [Bazarov, 2014, vol. 2: 91]. Then, after the processes have been proven analogical, a researcher is able to transfer the investigation method from one process (in Bazarov's case this source process is always natural) to another (social process that is to be studied).

In general, an economist could use analogies with other sciences in order to better present his ideas to the readers with different background, not necessarily trained in economics. Analogies could also become a tool of scientific discovery, when modelling of one phenomenon relies on already established theory concerning another phenomenon proven to be analogical to the first one. As for Bazarov, he used analogies as a tool of scientific discovery. Being trained as a chemist, Bazarov understood the mechanisms of natural processes and their mathematical interpretation. At the same time, since his youth he was closely involved in the revolutionary activity and wanted to contribute to the prosperity of the socialist project. While working on the elaboration of the first five-year plan, Bazarov realized that there was the lack of theory in many fields of Russian economic science. In 1927 he stated that "the theory of the recovery process dynamics is still in its infancy and, in fact, constitutes of a draft, provided by Groman several years ago" [Bazarov, 1927: 133]. Thus, Bazarov applied his skills of a natural scientist to creating economic theories that would help to build Soviet economy.

The present study examines Bazarov's restauration process model from the methodological point of view. It seeks to answer the following questions:

- how did Bazarov justified his analogic methodology, i.e. what made him think that the restauration process of the Soviet economy could be modeled in the image of an autocatalytic reaction?
- how was the model received by Bazarov's contemporaries?

- was the analogic thinking used by Bazarov actually appropriate for modelling the restauration process?

In order to fully understand the underlying motivation, which led to the creation of the restauration process model, it is necessary to analyze the major factors, influencing Bazarov's work on this model. On the one hand, his approach could be determined by the education that he received in the Moscow State University and in Berlin, and other personal factors, such as his interests, not connected to the work, his other activities (for instance, translation), his friends and family. On the other hand, methodology could be influenced by Gosplan as well, since the agency provided a social circle of colleagues, working together with Bazarov and helping him and/or opposing him. At the same time there was certain leading ideology and methodology, approved by the Communist Party, which everybody was supposed to follow. Moreover, one should take a look at other Bazarov's works, especially methodological ones.

Thus, the following structure is proposed to address the questions mentioned above: the first part of this work is devoted to the study of the factors that could influence the emergence of the restauration process model; the second section describes the model in detail and gives the answer to the first two questions, which are Bazarov's justification of analogic methodology and the perception of his model; the third part is suggesting a possible answer to the last question, whether the analogy was legitimate, and providing some conclusions. The first part is divided into four parts: the first describes the state of Russian economic science at the time of Bazarov's most active work; the second provides Bazarov's intellectual biography; the third is dedicated to the description of his work in Gosplan and the agency's peculiarities; next comes the fourth subsection titled "The law of conservation of social energy" which gives a reader an idea of Bazarov's attempt to build the social production dynamics theory in the image of the thermodynamics, his work prior to the restauration process model development. The second part contains three subsections: the first one gives an idea of Bazarov's view on analogic methodology; the second describes Bazarov's way of restauration process modelling; and the third one gives some feedback on the model from Bazarov's contemporaries. The last part has two subsections; the first provides recent feedback on the model, and the second draws some conclusions and suggests the possible lines for the further research of Bazarov's economic thought and analogic reasoning in economic scientific investigation.

Since Bazarov's works are not largely studied especially from the economic point of view, there is no much secondary literature to examine. Among the first works, dedicated to Bazarov, one can recall a PhD dissertation titled *The Political and Economic Thought of Vladimir Aleksandrovich*

Bazarov (1874-1939), which was written in 1994 by a western researcher, specialized in Russian history, Francis King. In his thesis King pointed out that above mentioned Erlich's book was in fact the first detailed analysis of V. Bazarov's economic thought. King's thesis is particularly valuable because it contains the first almost full list of Bazarov's works and his detailed biography [King, 1994]. Vincent Barnett, a well-known historian of Russian economic thought, in his work submitted for the PhD degree at the Institute of Soviet and Eastern European Studies (Glasgow University) mentioned that V.A. Bazarov was "somewhat known, but the detail of his economic theory remains uninvestigated by Western scholars" [Barnett, 1992: 4]. It was written in 1992, and was also true in relation to Russian scholars. During the Soviet Union times none of Bazarov's compatriots² studied his comprehensive vision of different research questions not only in economics, but also in politics, philosophy, and even literature. Only after the old regime collapsed at the sunset of the twentieth century some Russian researchers started publishing the studies of Bazarov's philosophical and economic views. In 2014 a publishing house of RANEP³ presented the collected works of V.A. Bazarov in two volumes. The present study will make great use of this edition, which contains an introductory article by Andrei Belykh and Vladimir Mau, protocols of Bazarov's interrogations, the memories of his grandson, and all the main speeches, articles, and books written by Bazarov. The list of Bazarov's works presented in this collection is exhaustive for the present study, where the focus will be made mainly on the book *Capitalist Cycles and the Restoration Process of the USSR Economy* [Bazarov, 1927] and two articles on the methodology of long-term planning: the one published by Gosplan [Bazarov, 1924], and another one published in the main journal about economic planification in the official Gosplan periodical *Planovoye Khozyajstvo*⁴ [Bazarov, 1926a]. Moreover, important insights were taken from the book, written by Andrei Belykh *The History of Russian Economic-mathematical Research. The First One Hundred Years* [Belykh, 2011]. The last but not the least main source is *Planovoye Khozyajstvo*⁵ journal. The corpus of literature studied to analyze analogic thinking in economics contains above mentioned book by Mirowski, Mary B. Hesse's book *Models and Analogies in Science* [Hesse, 1966], and some articles written by contemporary scholars.

² Actually, Vladimir Bazarov is mentioned in the book *Soviet economists of the twenties: names to be remembered* (1972) by Naum Yasny, an economist born in the Soviet Union. However, Yasny moved to the USA, his book about the Soviet economists was written in English, and published in London by Cambridge University Press [Yasny, 1972]. The book contains only the facts from Bazarov's biography, his political views, and some general information about his theoretical work.

³ The Russian Presidential Academy of National Economy and Public Administration.

⁴ Planned Economy.

⁵ All the quotations from Bazarov's works (and other sources published in Russian) given in this paper are translated from Russian by the author of the present paper (Elizaveta Burina).

Section 1. The framework that determined Bazarov's work

1.1. Russian economic science in 1920s

As it will be demonstrated, in the present study, Bazarov's analogic modelling was a means of the quantification of economic phenomena and an example of the use of mathematics in economic investigation. Andrei Belykh in his book devoted to the history of Russian economic-mathematical studies calls the 1920s the years of the "formation of Soviet economic and mathematical research" [Belykh, 2011: 45]. According to him, mathematical tradition in economics emerged during the period from the sixties of the nineteenth century to the beginning of the twentieth century. The lessons learned in that period were important for the further development of mathematical methodology in economics. Belykh also notes that the main factor that stimulated economic and mathematical research in 1920s was the extreme difficulty of the tasks faced by the country. To address the emerging issues, economists needed new approaches that would involve both quantitative and qualitative analysis. Moreover, in the period of the New Economic Policy (NEP) adopted by the Party in 1921, especially in its first half, the ideological control over economics was, in comparison with the subsequent periods of Soviet history, relatively mild [ibid]. Thus, the scientific environment of that time was one of the factors that encouraged Bazarov's work on economic modelling.

He published *Capitalist Cycles*, the work where he presented his most important analogic models, in 1927. By that time, some Russian and Soviet economists already presented their attempts to draw analogies between social and natural phenomena. For instance, a Soviet politician Nikolai Bukharin in his book *The theory of historical materialism* suggested the idea that a society consists of a certain number of individuals who have physical and spiritual relations. Both physical and spiritual interactions were determined by spatial distribution of individuals in a society. The interactions between individuals and particular systems including them were determined by the consumption of a certain amount of energy [Bukharin, 1922]. Bazarov was well aware of Bukharin's ideas and used them in his "the law of conservation of social energy" elaboration (subsection 1.4 of the present paper). Also, he used the ideas of professor A.N. Shchukarev⁶ presented in the article *Thermodynamics and Kinetics of Social Process* [Shchukarev, 1925] and his PhD student G.A. Prokopovich [Prokopovich, 1926]. A book by Ukrainian professor S.S. Ostapenko *Energetics of Social Economy* is also worth mentioning to give an idea of the set of

⁶ Alexander Nikolaevich Shchukarev (1864-1936) - Russian physicochemist, inventor, and the professor of the Kharkov Polytechnic Institute. He published more than 70 original scientific works and more than 30 works on the history of philosophy, some of them were translated into French German. The main works are devoted to chemical kinetics and chemical thermodynamics. Philosophical and "cybernetic" works of Shchukarev were not understood by contemporaries and were unfairly forgotten.

inter-disciplinary works existing by the time Bazarov started working on his models. Ostapenko's research tackles the same issue as Bazarov's "the law of conservation of social energy"; however, their approaches were different. Ostapenko was considering appropriate to sum up the amount of energy consumed by workers, cattle, and machines. Bazarov argued that it leads to the creating of "incredibly eclectic aggregates" [Bazarov, 2014, vol. 2: 37].

Thus, Bazarov had some material to build on while elaborating his analogic models. The common feature of the works mentioned above is the use of physical (more precisely, thermodynamic) phenomena as analogies to social ones. The findings of thermodynamics can be used in economics when it comes to the modelling of economy equilibrium in terms of used resources and produced goods. This is the case in Georgescu-Roegan's work, other western researches [Ayres, Nair, 1984], and also in one of Bazarov's models, the one considered in the subsection "law of conservation of social energy". However, the restauration process model was built by analogy with a chemical reaction. Thus, Bazarov was probably the one who introduced the use chemistry in economic modelling (at least in Russian economics).

Chemical phenomena lead to the emergence of new substances, while physical phenomena do not affect the molecular structure of substances. The difference between chemical and physical phenomena is that in the first case, the initial substances get destroyed, and in the second they remain themselves. Physical phenomena also cause changes, but of a different nature. For example, transitions to some other physical state. The shape, size, spatial position can also change. Thus, analogies with chemistry could be applied to economic processes in which there is a fundamental transformation. One of the models describing this kind of process is the restauration process model considered in the section 2 of the present work.

1.2. Intellectual biography⁷

1.2.1. Before the October Revolution of 1917

Vladimir Alexandrovich Bazarov (real last name – Rudnev⁸) was born in 1874 in the city of Tula in the family of doctors and scientists. The family was probably one of the factors that predetermined his further fascination with the natural sciences. He studied in the "classical gymnasium", that is to say, the high school where the main emphasis was made on learning ancient foreign languages (Greek and Latin), and pure theoretical mathematics. Moreover, after Bazarov

⁷ The main source of the biographical information is the article by Andrey Belykh and Mau published in the collection of Bazarov's works [Bazarov, 2014, vol. 1: 13-89]. The present paper also built on the facts provided by Yasny [Yasny, 1972: 189-207].

⁸ He adopted the last name "Bazarov" as an underground revolutionary pseudonym taking it from the nihilist character in Turgenev's *Fathers and Sons*.

graduated from the gymnasium in 1892, he spoke German, French, and English fluently. Right after gymnasium he entered Moscow State University, the best Russian higher education institution of that time. Bazarov enrolled in the Faculty of Physics and Mathematics, chemistry department. Since 1873 this department was headed by Professor Markovnikov, who laid the methodological foundations of teaching chemistry at the universities. Thanks to him, scientific work became a compulsory element of students' curriculum. In the end of 19th century, right before Bazarov had entered the university, the chemical laboratory was reconstructed and more practice oriented classes were added to the program. Undoubtedly, such university environment played its role in the formation of Bazarov's character and his professional interests. Even working on economic issues hereafter, he was using his knowledge of natural sciences.

Studying at the University, Bazarov began to participate in the social and political life of his homeland and engaged in revolutionary activities. He conducted propaganda in Tula and Moscow. Bearing in mind tense political situation in the Russian Empire in the end of 1880s-1890s, it is not surprising that the young scholar was persecuted, and then expelled from the University (in 1895) and, finally, expelled from Moscow and sent to Tula. Thus, Vladimir Bazarov did not have a chance to finish his undergraduate studies. In the questionnaire that he had to fill in 1924 as an employee of Gosplan answering about education he stated "completed the course, but could not pass state exams due to the exile" [Bazarov, 2014, vol. 2, p. 450]. Until 1900 Bazarov did not have right to live in the capital cities, he could not continue his studies therefore. He had been interested in philosophy before, but in exile he could invest all his time in studying it. In 1899 Bazarov published his first work *Productive Labor and Value Creating Labor* [Bazarov, 1899], where expressed his ideas of which labor should be called productive (as he found the inconsistency in Marx's vision of the concept⁹). Thus, he took a deep interest in Marx's philosophy already in the end of 1890s. As soon as he could be free to move again, he went to Germany where during two semesters he was attending lectures at the Faculty of Philosophy of Berlin University and doing research there. During that year in Berlin Bazarov, together with the other young social democrats who were living there formed the revolutionary group. They worked with the economists publishing the journal *Rabochee delo* in Geneva, with the revolutionists from the editor board of *Iskra* and *Zarya* newspapers.

Bazarov never studied economics, so the instruction that he had received in natural sciences and in philosophy determined the methodology that he further used in economic research. Some scholars even consider Bazarov as a philosopher rather than an economist, for example E.N.

⁹ Belykh and Mau explain Bazarov's position in their article, demonstrating that, in fact, Bazarov completed Marx's theory and did not contradict it.

Nikitin wrote about Bazarov and titled his article *Philosopher-collectivist* [Nikitin, 2002, p. 100]¹⁰. However, philosophical and economic components were always separated one from another in his works while economics and natural sciences were combined in a special way. The present study will come back to the analysis of this synthesis. Speaking about education, it is worth mentioning that not only what Bazarov studied, but also with whom he studied and interacted during his academic path had its influence on his views. An example of such important classmate is A.A. Bogdanov (real last name – Malinovsky) who was studying in the same high school as Bazarov and continued his education in Moscow State University (the same faculty, but one year earlier). Bogdanov was expelled and sent to Tula together with Bazarov, and they both continued their propaganda in exile. Later, the friendship with Bogdanov would play an important role in Bazarov's career.

After the two semesters in Berlin, Bazarov came back to Moscow and engaged actively in the work of the Moscow Committee of the RSDLP (Russian Social Democratic Labor Party), but at the very first party meeting all the members were arrested and exiled to the East Siberia until 1905. After his return he joined Bolshevik party and started working in Saint Petersburg as a leader of literature group. Later he became a member of editorial boards of all legal Bolshevik newspapers. Before the Menshevik and Bolshevik parties were reunited Bazarov kept working among the ranks of Bolshevik group, and after the integration he became a member of the editorial board of the united head office of the party. He participated in the famous 4th Congress of the Russian Social Democratic Labour Party that took place in Stockholm in April 1906, where he supported Lenin's view on "agrarian question"¹¹. Before the February Revolution he was arrested two more times, but did not stay in jail for long time and worked as an editor in different social democratic journals.

In this period Bazarov's interest in philosophy of Marxism was growing, and he published many articles on this topic (*Anarchical Communism and Marxism* [Bazarov, 1906]; *Mysticism and Realism of our Times* [Bazarov, 1908]; *On two Fronts* [Bazarov, 1910]; *On the Way to Socialism* [Bazarov, 1919]). In these articles Bazarov expressed his ideas of how to secure individual freedom; how centralized should a socialist society be; and also which methodology should be

¹⁰ See also: Nikolay Blohin *Philosophical publications of V.A. Bazarov and Russian Marxism in the beginning of the XX century* [Blohin, 2006]

¹¹ Lenin explained his position in his work *Agrarny vopros i "kritiki Marksa"* (Agrarian question and critics of Marx) [Lenin, 2017: 38] (chapters I-IX were written in June-September 1901; Chapters X-XII in the autumn of 1907). Lenin concluded that the economic controversial existing in the countryside showed the hopeless future situation of the small peasantry under capitalism. According to Lenin, the small peasantry could be freed from slavery and poverty only by fighting capital and only under the leadership of the proletariat.

applied to the analysis of the society moving towards socialist organization (he was inspired by the ideas of Ernst Mach and Bogdanov's empiriomonism). Philosophical questions were the first source of disagreement that Bazarov had with Lenin. The latter harshly criticized machists (here: adherents of Ernst Mach), especially in his work *Materialism and Empirio-criticism* [Ilyin, 1909] but the former did not agree with Lenin's judgement. However, there is an alternative view on Lenin's motives to write the abovementioned critical book. Yuri Felshtinsky, an American historian of Russian descent, revealed materials proving that Bogdanov (the most famous "mahist" and empirio-criticist) was Lenin's rival in getting control over the big sums of money intended for the Bolshevik party (Schmit's patrimony bequeathed to the RSDLP¹²). Felshtinsky claimed that, in fact, Lenin's critique of Bogdanov's philosophical views was just a formal reason for removing the latter from the floor [Felshtinsky, 2008]. At the same time, criticizing the position of Bogdanov, Lenin was also opposing Bazarov's point of view, since the latter shared machist ideas. Later, Bazarov quitted the Bolshevik party (in 1917, as his questionnaire for Gosplan workers states), and actively engaged in publishing and editing, considering himself as not belonging to any political movement or a particular party. Writing for the *Novaya Zhizn*¹³ newspaper, he expressed his views on the way of governing the new economic life. In Bazarov's opinion, workers' committees were not ready yet to independent self-regulation, and, therefore, he felt the need to use old State apparatus, i.e. centralized and following the unique plan. Lenin considered using this monarchy-like mechanism as unacceptable and extremely harmful. However, the first Soviet leader never called into question Bazarov's professional capabilities in economics, and at the same time. That was probably the reason why Lenin gave an order to free Bazarov and send him to Moscow when the latter was arrested in Crimea after the peninsula was finally occupied by the Red Army later in autumn 1920.

1.2.2. After the October Revolution of 1917

Bazarov was against the armed rebellion that the Bolshevik party was organizing in the beginning of October 1917. He believed that Bolshevik leadership had to "use every effort to keep the bewildered workers and soldiers from the insane step" [Bazarov, 1917: 1]. After the October Revolution he expressed his concerns about the established War Communism¹⁴ regime, pointing

¹² Nikolay Pavlovich Schmit – Russian revolutionary, the member of the RSDLP. Schmit actively participated in the organization of the 1905 Russian Revolution, was arrested and died in the Butyrskaya prison in 1907 (the writing on his tombstone reads: "brutally stabbed to death by Tsar's army"). Schmit left all his assets (280 thousand rubles) to the Party, those funds were enough to provide significant support almost until 1914.

¹³ In fact, *Novaya Zhizn* where Bazarov was working, was considered as a Menshevik edition (do not confuse with the eponymous Bolshevik newspaper). It was launched in 1917 but was closed down already in 1918 due to political issues.

¹⁴ War Communism (or Military Communism) is the name of the internal policy of the Soviet state, conducted in 1918-1921, during the Civil War. Its characteristic features were the extreme centralization of economic

at the disappointing consequences of the military coup: tremendous growth of bureaucracy, decreasing labor productivity, food shortages. Later in 1930 being brought into questioning on the so-called Menshevik process, Bazarov explained that, in his opinion, “the Bolsheviks artificially narrowed the basis of the revolutionary power and that, in addition to the internationalist and leftist Socialist Revolutionaries, the Mensheviks like Martov and some right-wing Socialist-Revolutionaries should have been brought into the government” [Bazarov, 2014, vol. 2: 458]. At the same time he did not bring himself to any political party, stating that during the October Revolution he had “serious disagreements with the Bolsheviks, and as a result became non-partisan since that time in order to preserve freedom of opinion in all political matters” [ibid]. There he also clarified his economic point of view on the War Communism policy: “Recognizing the inevitability of equalizing systems of distributing reserves, caused by the needs of the civil war, I also recognized that it was impossible to successfully build a socialist economy on the basis of military communism” [ibid, 459].

NEP “significantly weakened the disagreements” that Bazarov had with the Bolsheviks regarding economic issues. Abandoning War Communism policy gave the country a chance of economic development. NEP years were also the period of more freedom of thought in the Soviet Union. Belykh points out that “in the period of the NEP, especially in the first half of it, ideological control over economics was relatively mild compared with the subsequent periods of Soviet history” [Belykh, 2011: 46]. Belyh and Mau also noted that this period (namely, 1921-1928) was “special for Bazarov’s scientific work” [Bazarov, 2014, vol. 1, p. 43]. During his service in Gosplan Bazarov published his most outstanding writings in economics, including the theoretical work *Capitalist Cycles and the Restoration Process of the USSR Economy*¹⁵ [Bazarov, 1927]. One of Bazarov’s most important practical works the first annual economic plan, known as “Control Numbers” published in 1926 [Gosplan, 1926]. Together with Groman and Strumilin he was managing the work of statisticians and economists, the work based on theoretical methods. This plan, however, had never been used by the authorities¹⁶. Later, the second and the third annual plans were approved and taken into account, and Bazarov was again among those leading the work. He also participated in the elaboration of the first five-year plan, working mainly on the forecasting of the demand structure of urban population. Statistics was Bazarov’s strong suit; in 1926 he even

management, the nationalization of large, medium and even some small industries, the state monopoly on many agricultural products, the prohibition of private trade, the equalization of the distribution of material goods, the militarization of labor.

¹⁵ It was first published in 1926 as “Curves of development” of the capitalist and Soviet economy” in *Planovoye Khozyajstvo* [Bazarov 1926b].

¹⁶ The committee that was supposed to approve the first plan did not manage to gather [Strumilin, 1927: 11].

was the Chairman of Gosplan's Commission of the Economic and Statistical Section. In Gosplan he was always working alongside Vladimir Groman, whom he respected for the intelligence and hard work, and who became his friend. Groman was a Menshevik, and his close connection to Bazarov later became another reason to criticize the latter. One of Gosplan officers even called Bazarov "Groman's theoretical squire" [Vaisberg, 1931: 12]. Official public attitudes towards Bazarov and Groman changed in the late 1920s, as it will be demonstrated in the chapter "Perceptions of Bazarov's model" but before that both of them undertook a great work, trying to contribute to the success of planned economy. Working on all the theoretical and practical issues Bazarov defended the position that free market was an important part of the economy and even stated that the efficient planification was possible only under the assumption of the existence of well-functioning market mechanisms¹⁷.

The path of economic development suggested by Bazarov had never been accepted by the Soviet government. The second half of 1920s decade was characterized by the expedited industrialization and forced collectivization. This process went with disproportions and the economy was destroyed. By 1928 the Soviet administration started prosecution of so-called "pests" (in Russian: *вредители*) who were supposed to take responsibility for the mistake of the economic policy held by the Party. Stalin's government fabricated charges against Bazarov to accuse him of belonging to Menshevik Party and "bourgeois liberal movements". Bazarov's destiny was decided after Stalin's famous presentation at the agricultural conference on the 27 of December in 1929. The Soviet leader criticized equilibrium theory and the balance for national economy elaborated by the Central Statistical Directorate (in Russian: *ЦСУ*). He claimed that Bazarov's and Groman's approach to national economy balance preparation was unacceptable [Stalin, 1929a, p. 172]. However, that was unjustified criticism at least because Bazarov himself was not working on the balance preparation and repeatedly claimed being non-partisan. Soon enough Bazarov was arrested. The official confirmation was published on the 3rd of September of 1930 in the *Izvestia* newspaper: "OGPU¹⁸ arrested Kondratiev N.D., Groman V.G., Sadyrin P.A., Chayanov A.V., Yurovsky L.N., Sukhanov (Grimmer) N.N., Ramzin L.K., Bazarov V.A. and others for being participants and leaders of counterrevolutionary organizations, whose goal was to Soviet government overthrow and bringing capitalists and landlords back to power" [Izvestia, 1930, p.

¹⁷ V. Barnett showed how this Bazarov's position was criticized later in 1930 by his colleagues: "Strumilin responds by stating that socialism principally excludes free market elements. Calling the market a necessary precondition for all possible planning means that a price of renouncing socialism would have to be paid for such planning. By implication Bazarov is an enemy of socialism" [Barnett, 1992: 113].

¹⁸ Joint State Political Directorate.

5]. However, Bazarov unlike Kondratiev and Groman¹⁹ was lucky. He was released in 1932, moved to Saratov, then was living in the Caucasus, and in 1935 came back to Moscow. After that he was mostly working on translations²⁰. Bazarov translated *Philosophy of biology* by Le Dantec, *Talks to Goethe* by I. Ekkerman, and *Essays* by Montaigne. Nevertheless, the last years of his life were not that easy. As many economists and politicians being already arrested in the past, he was living under the constant threat of any new absurd charge. Fortunately, even if Bazarov was accused once again in opposing the regime, he was not arrested anymore. Some sources say he died in prison²¹, but that was not the case. Vladimir Bazarov died on the 16th of September 1939 of pneumonia. His grandson wrote a short note on his biography, describing the period after the last arrest as follows: “During the last years (1930-1939) it became absolutely impossible for Bazarov to do science though he continued his intellectual reflections. During the summer 1939 he told me that he got interesting ideas (seems like in the field of philosophy), which he wanted to write down. It was not meant to happen” [Bazarov, 2014, vol. 2, p. 487]. Belykh and Mau argue that Bazarov’s biggest tragedy was not only his numerous arrests, imprisonment, or exile. It was more the realizing that his ideals of the society did not come true [Bazarov, 2014, vol. 1, p. 89]. Undoubtedly, Vladimir Bazarov had a great mind and his ideas in the field of economics were and still are very valuable. The present study is a modest attempt to draw more attention on Bazarov’s exceptional way of thinking and his interesting vision of the economic dynamics.

1.3. Bazarov’s work in Gosplan²²

1.3.1. Early years’ work

Vladimir Bazarov started working in Gosplan in May 1921 in the Industry and Commerce Regulatory Commission²³ as a research officer. By that time he already had some academic experience in economics²⁴. As the first result of his work in Gosplan Bazarov formulated three principles of economic organization [Bazarov, 2014, vol. 1: 45]:

¹⁹ Nikolai Kondratiev was executed by firing squad in 1938, and Groman died in prison in 1940.

²⁰ Bazarov’s last publication in *Planovoye Khozyajstvo* (a speech) dated back to March 1930 [Krzhizhanovsky et al, 1930: 154-155]. It happened to be his very last scientific publication (during his lifetime), later he was only publishing his translations.

²¹ Naum Yasny claimed that Bazarov’s destiny was unknown and suggested that he most likely died in prison or was shot in 1937 during the Great Purge [Yasny, 1972: 207].

²² The information for this subsection was taken mainly from the article written by Andrey Belykh and Mau published in the collection of Bazarov’s works [Bazarov, 2014, vol. 1: 13-89] and a book *The history of Russian economic-mathematical research*. The first one hundred years written by Andrey Belykh [Belykh, 2011: 45-104].

²³ In the Sub-commission for accounting and distribution of material resources and labor organization.

²⁴ Bazarov’s grandson, Evgeniy Rudnev, in his memories of grandfather printed in the collection of Bazarov’s work told that together with Bogdanov Vladimir Bazarov was one of the co-founders of the Communist Academy, established in 1918. Before joining Gosplan research team he was working there as an academic leader of the office of ideology and theoretical economics [Bazarov, 2014, vol. 2: 477].

- 1) Direct administrative government intervention in industry and commerce is permissible only in relation to state enterprises, but not to private business. The rights and obligations of private traders and industrialists should be precisely and firmly established by the legislator so that representatives of the administration and the court are exempted from the need to resort to any discretion.
- 2) The central state authority should become to the direct organizers of state industry and commerce the same as the shareholders' board or the individual capitalist-owner, who does not personally manage the enterprise, is to the hired directorate.
- 3) Planification and regulation of the national economy should be separated from direct technical management of enterprises. Any combination of these two types of activity (for example, half private half public enterprises) is unacceptable.

Thus, Bazarov's views on economic policy were quite liberal for the Soviet Union. Back in 1922 one still could openly share such position without being labeled as public enemy. Belykh and Mau testify that Bazarov's report where he stated the three principles did not cause any serious objection during the discussion at Gosplan Presidium panel (at the same time, the principles were not taken as the basis of the state economic policy) [Bazarov, 2014: 45]. The work, accomplished by Bazarov during his early years in Gosplan resulted in his first publication written on the economic planning issues "To the Methodology of Long-term Planification" [Bazarov, 1924] printed in *Planovoye Khozyajstvo*. Belykh and Mau claim that it was the first ever Soviet theoretical work on the methodology of long-term planification. There Bazarov kept defending his position that free market was a necessary precondition for successful economic planning: "market together with khozyajstvenny raschet²⁵ gives, as to say, automatic estimation of the each industry performance <...>, and thus creates a mechanical counter that we currently need in order to gain at least some control of the state industry" [Bazarov, 1924: 2]. Creating of the well-functioning free market required the authorities to bring to a close emission financing of the economy and to establish a stable monetary unit. This explained Bazarov's interest in money emission issues.

1.3.2. Money emission theory

In November 1922 Bazarov participated as a panellist in a discussion on the report "Mathematical law of money emission" presented by O. Schmidt [Schmidt, 1923]. Belykh and Mau characterized that panel as "the first discussion on the use of mathematical methods in economics in the Soviet science" [Bazarov, 2014, vol. 1: 46]. In brief, Schmidt's work was a classic example of

²⁵ Khozyajstvenny raschet or hozraschet (in Russian: хозяйсчѣт) literally means "economic calculation". In the Soviet Union it was a method of calculating the costs and revenues of an enterprise in a planned economy, assuming a uniform distribution of part of the profits in favor of the "public" - employees of the enterprise.

mathematical modelling in economics, and the derived formula $\frac{du}{dt} = n \times u$ described the emission dynamics as growth at a constant rate (namely, exponential growth). Schmidt's theory was also supported by some statistical data. His report was commented by Preobrazhensky, Bazarov, Krizman, Larin, and Dvoylazky. Schmidt divided all the feedbacks in three groups: critique from those who completely understood his theory, from those who understood it partially, and from those who did not understand it at all. Bazarov's comments belonged to the first group [Schmidt, 1923: 274]. He claimed that Schmidt's findings were very interesting from the theoretical point of view but did not have any practical value. According to Bazarov, for the theory to be applicable to real monetary policy issues it had to be further elaborated [ibid, 265]. He suggested his own approach to calculating emission income and later developed it in the article "To the methodology of the money emission study" [Bazarov, 1923] published in *Vestnik Kommunisticheskoy Akademii* (The Herald of Communist Academy). There he pointed out a serious statistical mistake made by Schmidt: "instead of plotting individual months' fluctuations, he took an interval over a long period of time and then divided it by the elapsed time, which, of course, automatically smoothed the monthly variations of both positive and negative sign" [Bazarov, 1923: 68]. In other words, Schmidt conducted the stabilization of the time series which had already been stationary.

The main issue that Bazarov tried to address in his article from both theoretical and practical perspectives was the efficiency of money emission and the limits of this efficiency, so he build a mathematical model that would allow him to calculate emission income. Belykh and Mau claimed that Bazarov's work was too abstract and could not be applied as planned [Bazarov, 2014: 47]. However, "To the methodology of the money emission study" is particularly important for the present study because it was the first work where Bazarov brought up his idea of analogies between economic and natural processes. However, unlike the case of the restauration process modelling, in his 1923 article Bazarov did not use analogies as a method of scientific discovery. In fact, he only mentioned the parallels that he drew in a footnote, saying: "The reader, of course, has already noticed that the equations formulating the laws of emission are identical with the equations of ideal gases" [Bazarov, 1923: 57]. Bazarov's idea of the conformity of the emission law with the ideal gas law is captured in the table below.

Table 1 – Correspondences between economic and natural concepts.

Economic concept	Natural analogy
------------------	-----------------

Paper money supply, issued into circulation	Gas pressure
Exchange rate	Gas volume
Market capacity characterizing the energy level of system	The product of the ideal gas constant and absolute temperature
Emission income	Work done by gas due to expansion
Exchange rate stabilizing	The case when gas is heated from outside so that its elasticity does not decrease (despite the expansion)
Emission income in case market capacity is decreasing	Work of isentropically expanding gas, i.e. gas that does not receive heat from

Source: footnote [Bazarov, 1923: 57].

The list of economic concepts is placed in the first column for a reason. Bazarov built the model relying on his economic intuition and only afterwards noticed that the equation that he derived was already known in physics²⁶. Bazarov then claimed that it was not “a random analogy, not an amusing coincidence, but one of the innumerable examples of real unity, or, more precisely, the identity of the organizational structure in phenomena, the material composition of which is completely different” [ibid, 58]. Belykh claimed that the drawn analogy was perfunctory [Belykh, 2011: 80] but what matters is that already in early 1920s Bazarov was trying to justify the analogic reasoning in economic modelling.

Later the monetary system was stabilized (after the monetary reform, completed in 1924), and Bazarov focused on a new objective: the improvement of the long-term planning system. He published his first article on the theory of planification in 1924 (“To the Methodology of Long-term Planification” mentioned above) and then in 1926 wrote another article with the similar title “About the methodology of long-term plans building” also printed in *Planovoye Khozyajstvo* [Bazarov, 1926a]. Next subsection considers Bazarov’s main findings in economic planning and their influence on Gosplan’s work and Bazarov’s later interests.

1.3.3. Planification theory

Belykh stated that Bazarov was the first to develop the methodology of long-term planning [Belykh, 2011: 61]. In his 1924 article Bazarov distinguished two approaches to economic planning: genetic, based on the extrapolation of existing tendencies; and teleological, based on the directives. The first approach implied the use of what is now called econometrics, and the second

²⁶ The ideal gas law is considered here a physical (and not chemical) law since it involves such concepts as work, pressure, and energy.

required the authorities, setting the objectives for the economy, to have well-designed strategies for all the industries. Bazarov pointed out the division of the Soviet national economy into two fundamentally different sectors: state industry and small-scale agriculture. The former was suggested to be planned teleologically since it was fully in the public domain, and the latter was supposed to be planned genetically because of its more independent management. Bazarov made it very clear that only the synthesis of the two approaches provided the best methodology for the long-term planning: “the main task of the long-term planning leads to the need to combine genetic and teleological methods on the basis of finding the optimal path of development” [Bazarov, 2014, vol. 1:]. In his later articles Bazarov insisting on it: “teleology and genetics are not competing antagonists, but dialectically related moments of a single organic whole” [Bazarov, 1928: 38].

Unlike Bazarov, Gosplan officer split into two groups: the supporters of genetic approach and of teleological one. For instance, Groman gave priority to “genetics”, and Strumilin – to “teleology”. Groman believed that during the recovery process, the Soviet economy was striving for a state of equilibrium, following some empirical patterns described by a system of statistical coefficients. He stated that during the wars agriculture suffered less, but the speed of industrial recovery was faster, so he described the tendency as getting closer to the pre-war ratio of the comparative dimensions of agriculture and industry, 63% and 37% respectively [Belykh, 2011: 62]. Groman suggested focusing on these genetically derived figures when building long-term plans. Strumilin, who called himself a “communist planner,” put forward the development of a system of quantitative parameters, summarized in numerical series of a directive plan. Later in the end of 1920s this teleological approach would be approved by the Party as the only right methodology not contradicting communist ideology, and Bazarov would be unduly criticized for being a firm believer in the primacy of genetic approach.

1.4. The law of conservation of social energy

The money emission theory discussed in the section 1.3.2 was the first work where Bazarov mentioned the possibility of drawing analogies between economics and natural world. Later, he attempted to build a model of much bigger scale. This subsection is dedicated to the detailed investigation of the “thermoecomonic” theory developed by Bazarov and his model that was supposed to explain the dynamics of social production in the image of the laws of thermodynamics. He proved that the model itself could not be used in practice but the analogic approach became an indispensable tool for his further investigations.

In the beginning of the chapter II titled “Energetics and economics” of one of Bazarov’s main theoretical works *Capitalist cycles and the restoration process of the USSR economy* he pointed

out that the balance equations, describing national economy²⁷ were given in monetary terms, therefore, determined by prices. However, Bazarov stated that price ratios were enough neither to discover the conditions of the equilibrium of national economy nor to plan these conditions. There was a need for a theoretical structure that would “reveal real connections among different subsections of production and consumption that are only superficially explicitly reflected in the market in the form of certain price shifts” [Bazarov, 2014, vol. 2: 25]. Thus, the dynamics of “physical volume” (material quantity) of production was the subject of Bazarov’s investigation: he was looking for empirical regularities in the material processes of social production and reproduction. Once having stated that, he asked himself a question whether it was possible to apply to the social mechanisms the same natural laws that were successfully applied to any material mechanisms. Bazarov’s answer to this question was positive. In his opinion, the social mechanisms that were to be described could be reduced to labor relations. This core ideas is stated in the same chapter “Energetics and economics” as a definition of social relations: “In fact, social relations are, above all, the human ties established during the productive labor process, i.e. labor relations²⁸” [Bazarov, 2014, vol. 2, p. 26]. To justify the application of physical laws to these relations, Bazarov used the analogy, proposed by the Bukharin²⁹: workers of a factory could be associated to physical objects, and the society as a whole to a specific human labor machine where the majority of people or groups of people is taking a particular place in the production process [Bukharin, 1922: 96-97]. Therefore, concluded Bazarov, using the methods of physics and mechanics in social production analysis is absolutely justified. The chosen methods were actually borrowed from thermodynamics since Bazarov viewed the social production process as an energy exchange. He claimed that “the law of conservation of social energy” [ibid, 33] would provide a perfect theoretical system for formulating balance equations of the national economy and even for discovering universal regularities of the productive forces development³⁰.

²⁷ Here the term “balance equations of the national economy” refers to Marxian equations of simple and expanded reproduction, adapted to the Soviet economy.

²⁸ Later in this subsection, the notions “social relations” and “labor relations” will be used as synonyms.

²⁹ N.I. Bukharin was a Russian Bolshevik revolutionary, who started actively participating in political life being a student of the Moscow State University, in 1904. Afterwards he was exiled for six years and became very close with Lenin and Trotsky, who were also exiled at that time. Back to Moscow after the 1917 February Revolution he joined Bolshevik Party and had a successful career as a Soviet politician. Bukharin is also known as a scientist who worked on revolutionary theory. He wrote many theoretical and methodological books and articles. However, in 1929 he was suspended by Stalin because of his opposition to Stalin’s decision of proceeding with collectivization. Bukharin was arrested in 1937 and executed in 1938 as many other people objecting to the principles of the regime.

³⁰ The role of productive forces, specifically, labor force in Bazarov’s theory is very important. Bazarov’s business cycles theory states that the only way out of a depression is a positive labor productivity shock. Thus, his theory considered labor productivity growth as the main driving force of the capitalist cycle, which was quite unusual for the existing theories of that time, which assigned the role of the driver of the cycle to the technological shocks,

In order to elaborate a consistent useful theory of social production, Bazarov was to choose a measurement unit that was not monetary. Once again, following Bukharin's reasoning, Bazarov suggested that social labor could be expressed in any energy measurement units, for instance, ergs or calories. After defining the research question of the chapter, the methodology, and the potential difficulties of the associating social processes to natural ones, Bazarov provided a literature review, consisting mainly of the examination of above mentioned book by N.I. Bukharin, short remark on S.S. Ostapenko's book [Ostapenko, 1925], and very detailed description of the article, written by professor A.N. Shchukarev. Bazarov went further than Bukharin and stated that also the products of social labor could be expressed in the same measurement units. Thus, he obtained all the necessary assumptions for the social production to be subject to the same laws as any energetic phenomena. The major part of the model, presented by Bazarov in his book, was elaborated by Shchukarev and his input was fully acknowledged in the book. The explanation of the model starts with the equation for the increment of the internal energy of the system:

$$\Delta Q = \Delta U + \Delta A \quad (1)$$

where ΔQ is a quantity of heat, received by the system from the outside, ΔU is the increase in the internal energy of the system, and ΔA is the work of volume expansion³¹ (the system expands due to the energy received from outside). This means that a part of received energy is spent on the work of expansion, and the other part transforms into the internal energy. This equation can be easily re-written as follows:

$$\Delta U = \Delta Q - \Delta A \quad (1.1)$$

for illustrative purposes since it is the increment of the internal energy of the system, ΔU , that the study is interested in. Then, this increment could be broken down into different components, such as chemical energy, surface tension energy, etc. In the following equation the increments of these energy components are represented by the products $H_i \Delta m_i$, where Δm_i is the increase in the mass in each of the components, and H_i is the corresponding potential.

$$\Delta U = \Delta Q - \Delta A + (H_1 \Delta m_1 + H_2 \Delta m_2 + \dots) \quad (2)$$

reflected in capital. Bazarov associated labor productivity in social sciences with potential in physics, emphasizing that labor productivity characterized not the amount but the voltage of social energy.

³¹ In thermodynamics, work performed by a system is energy transferred by the system to its surroundings, due solely to macroscopic forces exerted by the system on its surroundings, where those forces, and their external effects, can be measured. An increase in work could be calculated as a product of the increase in mass, and the corresponding potential (potential energy is the energy held by an object because of its position relative to other objects, stresses within itself, its electric charge, or other factors).

Since the described system is the system of social production, there should be a specific component, reflecting psychophysical energy. It appears in the end of the equation below:

$$\Delta U = \Delta Q - \Delta A + (H_1 \Delta m_1 + H_2 \Delta m_2 + \dots + Z \Delta z) \quad (3)$$

Here, Δz is an elementary change in the psychophysical state, and Z is its potential. Professor Schukarev, whose ideas Bazarov used in his study, stated that this psychophysical potential increases in the proportion to the logarithm of the psychological values, introduced into somebody's mind. Cited by Bazarov, Schukarev pointed out that "it is easy to notice here the famous Weber-Fechner law in case we associate this potential to the intensity of sensations" [ibid, 40]. Schukarev proceeded with the generalizing of the psychophysical component to the group of social components, $W \Delta w$, where Δw represents the elementary quantity of a social good introduced to the system (which could be people, knowledge, ideas, etc.), and W refers to a corresponding potential.

Here is where Bazarov intervened with some critical notes and suggested the modification of professor Schukarev's analysis. First of all, he called into question the appositeness of the Weber-Fechner law in this framework. Bazarov listed some salient features of this law, making it difficult to apply the law to the thermal analysis of the social production:

- The given thermodynamic system allows to distinguish any special component of energy (as it was stated above, one could think of chemical energy, surface tension energy as elements of the system's energy in a global sense). However, it is possible only if the new components are measurable, which is not the case for psychological experience, according to Bazarov. He further explained why it was not possible to strictly measure the input of the "psychophysical" element of Schukarev's model.
- The mere formulation of Weber-Fechner law as "the intensity of sensation increases as a logarithm of the stimulus" (Fechner's law) did not allow measurement in mathematical sense. Bazarov referred to the experiments proving that the just noticeable difference is proportional to the initial stimuli (Weber's law)³². Thus, the just noticeable difference is neither a differential, nor even a finite difference. Bazarov concludes that "any mathematical formula that binds quantitatively incomparable increases in perception with quantitatively comparable increases of stimulus is basically vicious.

³² Interestingly, Bazarov referred here not to Weber's experiments, and not even to Fechner's formalization of those experiments, but to the work of Wilhelm Wundt, *Grundzüge der psychologischen Psychologie*.

- Even imagining that the intensities of sensations could be quantitatively measured, Bazarov did not see the way to make use of Weber-Fechner's law in his system of thermodynamic description of social production. The problem is the subjectivity of perception. The *just noticeable difference* changes from person to person. Fechner himself was emphasizing this fact. For instance, he mentioned that the ability to perceive differences in light intensity could be related to how good that individual's vision is [Fechner, 1966].

Bazarov concluded that the psychophysical component could not be introduced to the equation of energy conservation. Moreover, he claimed that it was impossible to apply energetic logic to the psychological phenomena because that would break the law of the conservation of energy. The quotation, given below, reflects Bazarov's logic:

"Indeed, let us assume that an act of our consciousness gets some energy from our nervous system when it emerges, and gives the energy back when disappears. <...> In the moment of the emergence of this conscious act, which cannot be measured in any objective manner, the part of energy would vanish into thin air. Vice versa, in the moment when the conscious act fades away, we would register the appearing of some energy out of nowhere" [Bazarov, 2014, vol. 2: 42].

Thus, Bazarov rejected the possibility of describing the psychophysical element of the energetic system of society according to the Weber-Fechner's law. Interestingly, he accepted Schukarev's idea of introducing the "social" component ($W\Delta w$). However, he significantly decreased the variety of the "mass increment" part. While for Schukarev this category could include people, goods, knowledge, ideas, Bazarov focused only on "masses of consumption values". Obviously, he viewed the measurability of the components as one of the most important assumptions for building the theoretical energetic model of social production. His model was supposed to be mathematically and physically rigorous, but was it corresponding the economic reality of that time? The answer given by Bazarov himself was no. He found it problematic to measure the main component of the system of social production – social labor. The issue was rooted in the question whether the social significance of labor in different sectors could be measured by the same energetic units. A good example here could be the comparison of physical and intellectual labor. Even in the case when people who work in knowledge industries and those engaged in physical work produce the same exchange values, they definitely spend different numbers of calories. Thus, Bazarov concluded that the measurement of social energy by "working time" (Marx's idea) could not be reduced to energy units. Measuring the product of labor by the amount of ergs (or calories) spent on its production or kilograms-meters of work would give not the social value, but some

physical quantity devoid of any significance. Thus, the failure of drawing an analogy resulted from the measurement issue, i.e. the conclusion that social potential or unit labor cost could not be expressed in conventional energy units.

This model could be included in Mirowski's *More Heat than Light*, which is, probably, one of the most complete studies of intermingling of economic and physical methods, where the author comprehensively demonstrates that the interconnections between economics and physics and their research programs are stronger than one could think: "the resemblances of the theories are uncanny, and one reason they are uncanny is because the progenitors of neoclassical economic theory boldly copied the reigning physical theories in 1870s" [Mirowski, 1991: 3]. Mirowski provides examples of "translation" of economic models into the language of physics, demonstrating the underlying identities. Since physicists came up with those models before the neoclassic economists, he concludes that it was economics that merely copied the findings in physics. Mirowski focused mainly on the concepts of value in economics and energy in physics, and these two core notions are also a subject of one of theoretical systems, build by Bazarov. However, the latter was using not only the energy conservation law for explaining social production process and value transformation, but also many other regularities, borrowed from chemistry and physics. Even though Bazarov's attempt to build the complete socio-economic theory in the image of thermodynamics failed due to a measurement issue, he did not abandon the idea of borrowing modelling logic from physics, and the examples of analogic modelling by Bazarov will be also provided in the next section. Mirowski's lesson about using natural sciences in economics is simple: "perhaps we may learn from physics without feeling that we must be physics" [Mirowski, 1991: 401]. *More Heat than Light* is distinguished by the expressiveness, and, at the same time, conciseness of the wordings. It took Bazarov a paragraph to express an idea that is strikingly similar to Mirowski's. The Russian author claimed that even though the scientific caution, forcing us to refrain from building a general theory of social force fields, is understandable (since "to perform such a task we need a genius of the scale of Isaac Newton" [Bazarov, 2014, vol. 2: p. 56]), using analogies with natural world in modelling some particular cases of economic activity could be a success. In Mirowski's terms, building a general theory of social force fields would mean "be physics", and using constructions built to reveal the structure of a certain special process, or in other words, borrowing established rules from natural sciences to explain certain social phenomenon, would mean "learn from physics". An example of learning from natural sciences in Bazarov's work is his restauration process model, which is the subject of the following chapter. The model had an important objective: address omissions in Gosplan's theoretical framework. In the mid-1920s, when Bazarov was working on his model, after the economic and

political system of “War Communism” (or “Military Communism”) ended and was replaced by the New Economic Policy, the crucial issue was the rehabilitation of the economy, destroyed by international and civil wars. Bazarov emphasized that by the moment when the New Economic Policy was launched, the Soviet industry “constituted the opposite of any adequately organized system, where the right man is in the right place” [Bazarov, 2014, vol. 2, p. 136]. That is why he focused on the modelling of the recovery phase of the business cycle, in line with Gosplan’s work on the first five-year plan. Building a model that would formally describe the quantitative regularities of the recovery was necessary for genetic planification. Bazarov considered genetic and teleological approaches complementary and recognized the importance of both of them. He viewed the combination of these approaches as the implementation of the unity of the plan and the market in the practice of planning. Since the present study focuses on the economic theory developed by Bazarov, it will not investigate in detail his views on teleological planning. Genetic approach is the one requiring economic justification, and Bazarov was seeking to provide it. Thus, the restauration process model was supposed to give the idea of how the recovery would go, and the predictions were supposed to be made based on the market trends.

Section 2. Analogic modelling of the restauration process

2.1. The role of analogies in Bazarov's work

Before proceeding to the detailed study of Bazarov's model it is important to investigate a deeper methodological issue, raised by Bazarov, namely the scientific relevance of analogic reasoning as a method of social processes formalization. To him, analogies with physics and chemistry served as an instrument of scientific research. As it has been shown in the chapter "The law of conservation of social energy", Bazarov's attempt of building the complete socio-economic theory in the image of thermodynamics failed due to a measurement issue. However, he did not abandon the idea of borrowing tools from physics completely. But what were his arguments in favor of this method? Why was he sure that the inference of an analogic model was reliable? Mary B. Hesse in her book *Models and Analogies in Science* [Hesse, 1966], in the chapter "The Functions of Models: a Dialogue" considers the example of modelling the phenomena of light and electromagnetism in the image of mechanical models. She brings up the point of view of Pierre Duhem who admits that analogic approach in this case could be only useful psychological aids, but not more than that [Hesse, 1966: 2]. Duhem emphasized that there was no reason to believe that analogies could help in building significant models [Duhem, 1906]. A similar opinion is shared by Mary S. Morgan who concluded that "analogical devices are certainly of help, but do not provide a complete substitute for model-building decisions" [Morgan, 1999: 386]. On the other hand, Hesse demonstrates how the analogy method could work in physics with the words of her protagonist, Campbellian, who describes "Campbell's well-worn example of the dynamical theory of gases". Campbellian says that using analogies is justified and could be a scientific method if the phenomena are actually identical. He admits that phenomena could also have "negative analogies", i.e. properties inherent to one phenomenon and not found in another one. Consequently, some characteristics shared by both the phenomena are named "positive analogies". There is a room for scientific discovery through so-called "neutral analogies", the properties, in the words of Campbellian, "about which we do not yet know whether they are positive or negative analogies; these are the interesting properties, because, as I shall argue, they allow us to make new predictions" [Hesse, 1966: 8]. According to this Campbellian approach, scientists are supposed to carefully analyze the properties of the phenomena seeming to be identical, in order to distinguish those "positive" and "negative".

Bazarov's approach is close to Campbellian's in terms of the role of analogies in the construction of models, since Bazarov viewed analogies as a tool of formalization, and used the "neutral analogies" for scientific discovery. He stated that in order to apply any law derived for chemical or physical phenomenon to the quantification of a social process, the latter should be studied in

detail to be recognized as similar to the former. For a layperson “similar” is only a vague concept, while in science the similarity has to be proved. In Bazarov’s view, qualitatively different phenomena could be modeled in the same way if and only if they had identical internal organizational linkages, if they were formally identical, if they had the same structure. Bazarov claimed that analogic method was widely used in the natural sciences, where the phenomena is not less (and quite often even more) complicated than social ones [Bazarov, 2014, vol. 2: 91].

This is, however, his only remark on the general question whether or not the using of analogies with natural processes in modelling of social processes was methodologically justified. In the first case of the market saturation process modelling, Bazarov made sure that the market saturation process was structurally identical to the reaction caused by adding a significant amount of hydrochloric acid to the solution of sodium bicarbonate. Using this analogy was justified by adding extra assumptions to the market framework (such as constant price, absence of speculative resale, etc.), and special conditions to the reaction (such as the amount of one reacting substance was very large in comparison with the amount of the other). Bazarov claimed that he had discovered actual resemblance of the two mechanisms, and those extra conditions were not changing their core structure. In terms of Campbellian, adding these assumptions meant eliminating possible “negative analogies”. Doing this brought Bazarov’s approach to a case, approved also by Duhemist from Hesse’s book, who expressed an idea that in case the positive analogy between two phenomena is believed to be complete, and there exists a model (let us name it $model_1$), describing one of them, and the other one still needs to be described theoretically, and then “there is no harm in using the language of the $model_1$ as an interpretation of the mathematics of the theory” for the second phenomenon.

After demonstrating some parallels of Bazarov’s thought with the ideas of both Campbellian and Duhemist, it is worth reminding that Hesse’s protagonists were arguing over the analogies inside physics (whether it be kinetic theory of gases built in the image of billiard-balls model or modelling sound motion using the equations of water ripples). Bazarov was tackling a more complicated issue: creating quantitative social-economic theories by analogy to the models from natural science. Borrowing the models from the latter he was trying to solve the problem of the lack of quantification in social sciences. He shared with his readers an opinion common for the scientists of that time, an opinion widespread in Russia, that there was the juxtaposition of natural and social sciences; however he himself was never supporting this point of view. Here is an example from *Capitalist Cycles*: “It is often claimed that, unlike physics and chemistry where strict regularities and unambiguous functional relations are prevailing, social life is in its essence alien to functional relations and allows only for some correlations. There is no way to agree with it.” [Bazarov, 2014,

vol. 2: 56]. In Bazarov's opinion quantification in social framework was possible and, moreover, necessary and yet missing, and the findings from natural sciences could help to make up for this shortfall.

2.2. The description of the model and the role of analogies

2.2.1. Model 1

In order to fully understand Bazarov's approach to modelling a part of the business cycle, one should be familiar with his ideas of the mechanics of the whole cycle. In brief, Bazarov describes it as follows: global overproduction of the *crisis*, going through the equilibrium of *depression*, changes to relative underproduction of the *recovery* phase. At this point it is not needed anymore to stimulate sales by lowering prices, so the prices first stabilize, and then start growing, following the upward wave of the production cycle. This, in turn, encourages banks activity; credit operations expand, stimulating the improvement of economic conditions; here the new cycle begins [Bazarov, 2014, vol. 2, p. 66]. Approaching the quantitative study of the cycle, Bazarov simplified the framework, getting rid of both the lowest (crisis) and the highest (economic boom) points of the capitalist cycle curve. In order to remove the boom stage, which is the end of the recovery process, Bazarov eliminated the capitalist credit system. He assumed that this system either did not exist at all or it was managed by the government³³, which would systematically adjust all the financial credit processes.

Thus, the analysis started at the underproduction point, and the main research question was: at what pace would the production "recovery" (or expansion) go³⁴? [Bazarov, 2014, vol. 2, p. 93]. To answer this question Bazarov built a framework of the two differential equations. The first one would describe a particular case when there was already an established demand on the market of a certain good, but there was no supply at all. It was then assumed that the supply of this deficit good had increased immediately (for instance, due to its import), and since that time the quantity of supply was enough to satisfy the demand. The second case was similar, but more general and more realistic. It was supposed that when the static equilibrium of the depression phase was disturbed due to conquering a new market or technical improvements of internal production, there had not been any established demand yet, so the new goods (which were less costly to produce, and thus, cheaper) were appearing first in small quantities. The new goods were competing for consumers' demand with already existing goods. Let us consider each case separately.

³³ Making this assumption Bazarov implied a benevolent government that would manage the credit system efficiently.

³⁴ Since there was no credit, all the demand is "real", therefore Bazarov expected the process of saturation to go smoothly, with no crisis or rush.

Bazarov stated that in the first case a certain good would be sold very quickly in the beginning when it only appeared, and then the pace would decrease with meeting the demand. To model this kind of dynamics Bazarov needed five more assumptions:

- 1) there were no substitutes for the good, appeared in the market;
- 2) the price of the good did not change;
- 3) each consumer bought more or less the same amount of the good as the others;
- 4) there was no repeat purchasing (since the consumer value of the good was quite stable);
- 5) there was no room for speculative re-sale.

Given all these conditions, Bazarov considered it not hard to find a “structural analogy between the process of market saturation and well-studied processes of transition from level difference to equilibrium in chemistry and physics” [Bazarov, 2014, vol. 2: 94]. As it was explained in detail in the first part of the present work, Bazarov relied on research methods from natural sciences mainly because he was educated as a chemist, not an economist, and knew these methods well. At the same time, he was not satisfied with the business cycle theories, already existing in Russian economic science³⁵. Bazarov resorted to the regularities, formally established in “hard sciences”, considering them being analogical to economic ones, because for him it was an obvious reliable way of scientific discovery. He noticed, however, a common formal difference between chemical reactions and market mechanisms: once sold, a good disappeared from the market and had no more influence on the rest of the goods, still staying on the market. The products of a reaction do not usually disappear; instead, they are interacting with the initial reagents and with themselves. Another difference concerned the amount of reagents. In chemistry, the greater is the concentration of the reacting substances, the greater is the extent of chemical interaction. The same regularity is usually observed on the market: the more buyers, the faster the offtake. However, a shortage also increases the speed of selling. At the same time, if the supply exceeds demand, in other words, if there is more product available than the buyers are ready to purchase, there is no impact on the speed of trade³⁶. In chemistry, an increase in the amount of one reagent does not have any impact on the reaction speed only if from the very beginning the amount of this reagent was big enough, so the concentration could not change significantly in case of an increase in this amount.

³⁵ One can find critical analysis of Tugan-Baranovsky's and Kondratiev's business cycle theories in Bazarov's *Capitalist Cycles*. In fact, Bazarov provided “the most serious analysis, mainly from the formal methodological side” as wrote A. Svetlov in his review on Kondratiev's *The Major Cycles of the Conjuncture* [Kondratiev, Oparin, 1928]. The review was published in 1929 in *Planovoye Khozyajstvo* [Krzhizhanovsky et al, 1929].

³⁶ Given the assumption of constant prices, made by Bazarov before.

Thus, considering the restauration mechanism, Bazarov stated that in order to apply the chemical logic to this economic process it was crucial to assume that the amount of one reacting substance was very large in comparison with the amount of the other, and the reaction product was immediately removed. Bazarov gave an example, describing this very process. Let us imagine adding a significant amount of hydrochloric acid to the solution of sodium bicarbonate. The following table represents the analogies made by Bazarov in structurally similar processes: the transformation of the sodium bicarbonate into the sodium chloride and the sale of a unit of a certain good in the market.

Table 2 – Correspondences between chemical and economic processes

Chemical process	Economic analogy
A molecule of the sodium bicarbonate meets a molecule of the sodium chloride.	A buyer who needs a good actually finds it in the market.
The product, obtained after the interaction of the hydrochloric acid and the sodium bicarbonate, carbon dioxide, goes away to the atmosphere.	After the interaction between a seller and a buyer happened, and a unit of good has been sold, this unit disappears from the market.
The reaction goes all the way to the end, i.e. to the transformation of all the molecules of the sodium bicarbonate into the molecules of the sodium chloride.	The sale of a good goes all the way to the full demand saturation, i.e. until all the consumers who need a good and are able to buy it, actually get it.

Source: Bazarov, 2014, vol. 2, p. 96-97. Tabular format suggested by the author of the present paper.

The fact that the movement of consumers is not completely random as it is the case for the molecules, convinced Bazarov that the market process could be modeled in the image of the chemical reaction. He said: “Since we are dealing with massive and anarchic market process there is no reason to believe that statistical patterns will work less precisely in market process modelling than in kinetic theory of gases or theory of solutions” [Bazarov, 2014, vol. 2, p. 97]. Referring to Maxwell’s inference that all of the molecules move with the same speed on average³⁷, Bazarov assumed that the average probability for the potential purchaser to come across the product remains

³⁷ Maxwell proved that whatever initial speeds we give to individual molecules, after a very short period of time equilibrium establishes, at which the deviations of individual velocities from the average, determined by the conditions of experience, will exactly follow the Gauss law. It can be therefore assumed that all molecules move at the same average speed and, therefore, each of them has the same chance of colliding with a hydrochloric acid molecule over a given period of time (Bazarov’s additional explanation [Bazarov, 2014, vol. 2: 97]).

constant throughout the entire process. Forming the differential equation, describing the pace of sales, Bazarov denoted this probability as p . He took then x for the number of consumers who have managed to buy some of the product by the time of the observation, and A for the number of all the consumers who need the product. Then $p \times (A - x)$ is the mathematical expectation of the number of purchases per a unit of time. According to Bazarov, this number is equal to the speed of the process at the moment of observation which is expressed by the differential value $\frac{\partial x}{\partial t}$. Thus, the equation has the following form:

$$\frac{\partial x}{\partial t} = p \times (A - x) \quad (4)$$

After solving the equation one obtains the following result³⁸:

$$x = A + C \times e^{-pt} \quad (5)$$

Bazarov presented the result a bit differently [ibid, 98]:

$$A - x = (A - x_c) \times e^{-pt} \quad (6)$$

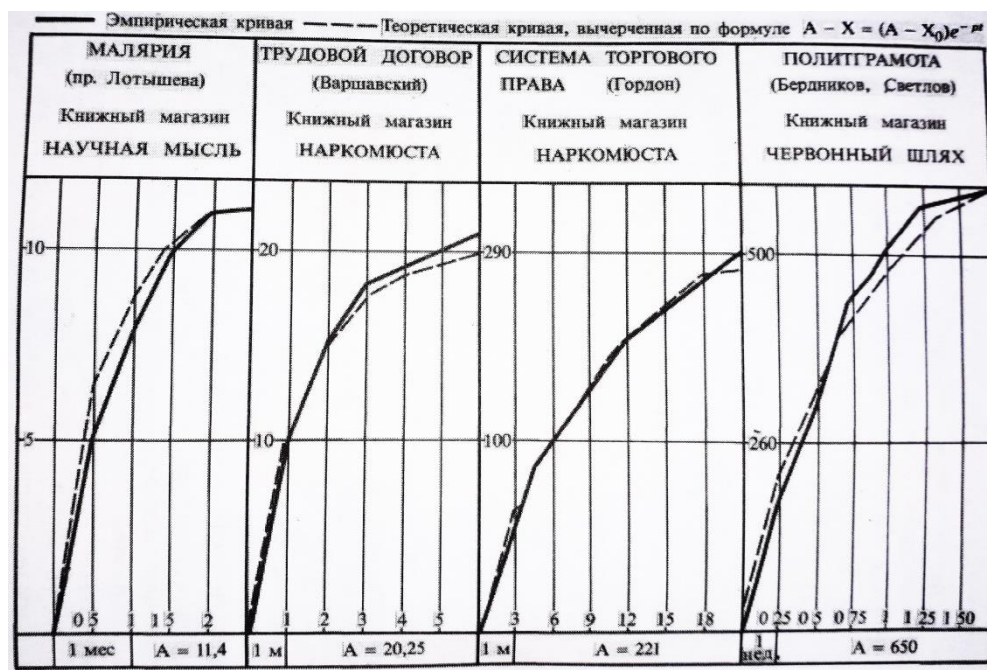
since he was interested in the modelling of the number of consumers who still did not get the product by the moment of observation as a dependent variable. Thus, equation (6) is an expression for the law of market saturation (with all the assumptions made before), more precisely, the pace of this process depending on time. The curve which represents the change in market saturation depending on time goes up faster in the beginning, and slower afterwards, asymptotically approaching the level of A (which means that x , the number of consumers who have managed to buy some of the product by the time of the observation, converges to A , the total number of consumers willing to buy the product).

This first case is a simplified one because of the assumptions made in the beginning of the analysis. However, Bazarov managed to find an example from the real life which corresponds to this case. He referred to the work of a PhD student G.A. Prokopovich who studied the case of four new published books and the speed of their realization in the market [Prokopovich, 1926]. This example complies with the requirements set by Bazarov: absence of substitutes, constant price, stable consumer value, the need of a huge number of consumers for a unit of the product, no re-sales. The graph below merges the empirical results, obtained by Prokopovich and the theoretical inference, developed by Bazarov. The vertical axes represents the number of books sold (or the number of consumers who have managed to buy a desired book), the horizontal axes counts the

³⁸ C is the constant resulting from solving an indefinite integral.

amount of time passed from the publishing (one marking is equal to one month for the first three sections, and one week for the last one). The black line depicts the number of books sold in the three bookstores in Kharkiv, a Ukrainian city where Prokopovich was working. The four sections correspond to the four books (the first book, *Malaria*, was traded in the shop “Nauchnaya Mysl”, the second, *Employment contract*, and the third, *Commercial law system* was traded in the shop if Narkomust, and the fourth, *Political literacy* – in the store called “Chervonnyi shlyah”). The dashed line is a theoretical curve built upon Bazarov’s equation (6). The results are quite impressive, especially because the empirical study was made for four books only and with not many observations available. With the help of this example Bazarov showed that even the first (simplified) version of his model is able to describe real market processes.

Figure 1. The dynamics of the number of copies sold.



Source: Bazarov, 2014, vol. 2, p. 100.

2.2.2. Model 2

After the analysis of the first particular case, Bazarov proceeded to the more general one. In this second case the process of recovery does not start from the sharp increase in the supply of a good. Instead, we're observing a gradual growth of its amount, appearing in the market. According to Bazarov, in the very beginning when the potential demand significantly exceeds the supply, sales will increase in proportion to the quantity that has already been sold. As the demand gradually tends to saturation, and the number of potential consumers buying outdated products decreases, the process slows down, asymptotically converging to a new level. Also for this process Bazarov has found an analogy with chemistry, which is an autocatalytic reaction, where each molecule

stimulates the creation of the new molecules of the same structure. The speed of this process is, on the one hand, proportional to the number of newly emerged molecules, and on the other hand, similarly to the first case considered earlier, stays proportional to the number of molecules still not involved in the reaction.

In the second differential equation, x is the amount of production (or its realization), associated to the number of already reacted molecules, A is the new level of the market, reached as a result of the increase of labor productivity, associated to the total number of molecules in the chemical process. Thus, $\frac{\partial x}{\partial t}$, the speed of the process, equals to the $kx(A - x)$, where k is a constant coefficient. The equation looks as follows:

$$\frac{\partial x}{\partial t} = k \times x \times (A - x) \quad (7)$$

Bazarov solved it and obtained his main law of the recovery process, which he represented this way [Bazarov, 2014, vol. 2: 102]:

$$\frac{\ln Cx}{A-x} = Akt \quad (8)$$

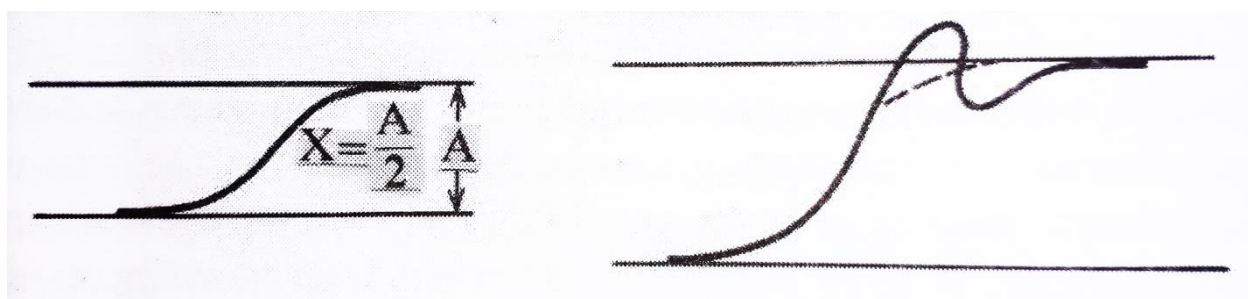
When x is small, the value of $(A - x)$ does not change significantly with an increase in x , so the speed of the process is proportional to x . When x reaches the level of $\frac{A}{2}$ the acceleration of the process due to growing x is compensated by the slowing down due to a decrease in $(A - x)$, so the speed becomes constant for a moment. Afterwards, with further increase in x and, therefore, decrease in $(A - x)$, the process slows down and then it is terminated when x equals A , i.e. all the molecules reacts or a new level of equilibrium is reached. Graphic representation of this dynamics is an S-shaped trajectory that will be illustrated below.

The formula obtained by Bazarov was also used in biology by an Australian physiologist and biochemist T.B. Robertson. He was working on biological growth theories, and has found this formula quite universal for the nature. In Robertson's book *The Chemical Basis of Growth and Senescence* [Robertson, 1923], brought up by Bazarov in this *Capitalist Cycles*, Robertson suggested that the formula could express the main law of biological growth, while an animal could go through several successive S-shaped growth cycles. It is possible that Bazarov's inference was inspired by the work, conducted by Robertson only four years before the publication of *Capitalist Cycles*. This parallel between Bazarov and Robertson was drawn also by a Russian economist Nikolai Kondratiev, who, according to the testimony of P. Klyukin [Klyukin, 2014: 237], requested both works: *The Chemical Basis of Growth* and *Capitalist Cycles* while being in exile

in Suzdal. During that Suzdal period Kondratiev was carrying out a research trying to come up with an equation for his theory of economic growth, for which he was studying the literature on the dynamic theory of population.

Bazarov reminded his readers that this curve can explain the restauration process under the no-credit assumption. At the same time, “under the rule of classical capitalism, formula (8) pinpoints the main objective law of the dynamics of productive forces (labor productivity), and not of their physical volume” [Bazarov, 2014, vol. 2: 103]. The following diagram represents the two graphs together, i.e. the dynamics of labor productivity (represented by the equation (8)) and the dynamics of production volume, obtained by logical transformations of the equation (8).

Figure 2. Labor productivity dynamics and production dynamics.



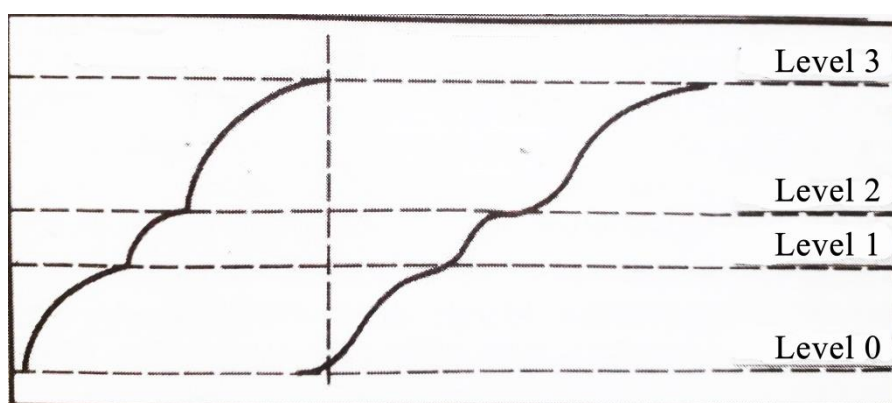
Source: Bazarov, 2014, vol. 2, p. 104

Bazarov admitted that the two equations (6) and (8) were quite primitive and could be considered only as approximation. However, he claimed that they still could help to indicate the direction of social planning [Bazarov, 2014, vol. 2: 103]. He also used the restauration process model, represented by the equation (8) for his further investigation of business cycles. In his opinion, cycles could not be considered as temporary deviations from an “evolutionary level” immanent to capitalism³⁹. Instead, Bazarov believed that the reasons that cause the transition from the lowest point of the cycle to the highest through the stages of depression, recovery, expansion and crisis, are the main driving forces of economic development in the capitalist era. It means that no real trend, apart from actually occurring cycles, is hidden in the capitalist economic system, and, consequently, the cycles are not the deviations from some permanent evolutionary trend, but its elements; the growth curve does not “smoothly” pass between zigzags of cycles, instead, it goes through zigzags, includes them, represents simply the sum of individual cycles. Determining a formal expression of this curve for the USSR economy was one of Bazarov’s ultimate goals, and

³⁹ This means: capitalism has forces under the influence of which, the national economy tends to grow smoothly, following a certain pattern, along a certain mathematically defined curve; but under the influence of particular causes, the actual line of capitalist growth undergoes a series of deviations, which in turn are partly regular and periodically repeated at same intervals, partly irregular and non-periodical.

to achieve it he used the results, obtained from the restauration process study. He viewed the cause of fluctuations in shifting from a certain level⁴⁰ of labor productivity⁴¹ to another. The dynamics in between the levels, i.e. restauration process, could be modeled in different ways. The figure 3 below represents this idea: the first curve on the graph corresponds to the process, described by the formula (6), and the second curve is a representation of the formula (8).

Figure 3. Graphic representation of business cycles, described by the formulas (6) and (8).



Source: Bazarov, 2014, vol. 2, p. 107.

2.2.3. Statistical analysis

Together with the theoretical arguments in favor of analogic models, Bazarov gave some empirical proofs of their validity. One of them was presented in the previous chapter, illustrated by the figure 1; it was the dynamics of the number of copies sold, very closely following the predictions, obtained with the help of the formula (6). Not only this formula for a very particular case had been proven right by Bazarov with an empirical example, but also the second formula, obtained by analogic modelling using an autocatalytic reaction as a prototype, had some correspondences with the Soviet economic reality. The approximate⁴² quantitative description of the first years of the restauration process (1920-1925) in terms of industrial production was considered in the Capitalist Cycles in the 7th chapter titled “The general curve of the recovery process in the industry of the USSR”. According to that approximate calculation, in 1921-1922 gross output of state industry grew by more than 40% compared with the previous year. The next year’s growth reached the level of 31%, and a similar figure of 30% was observed in a year 1923-1924. The fourth year of the recovery, 1924-1925, demonstrated the results that surprised Gosplan’s researchers: while the most optimistic predictions for the production growth were 30-35%, it in fact constituted for 60%.

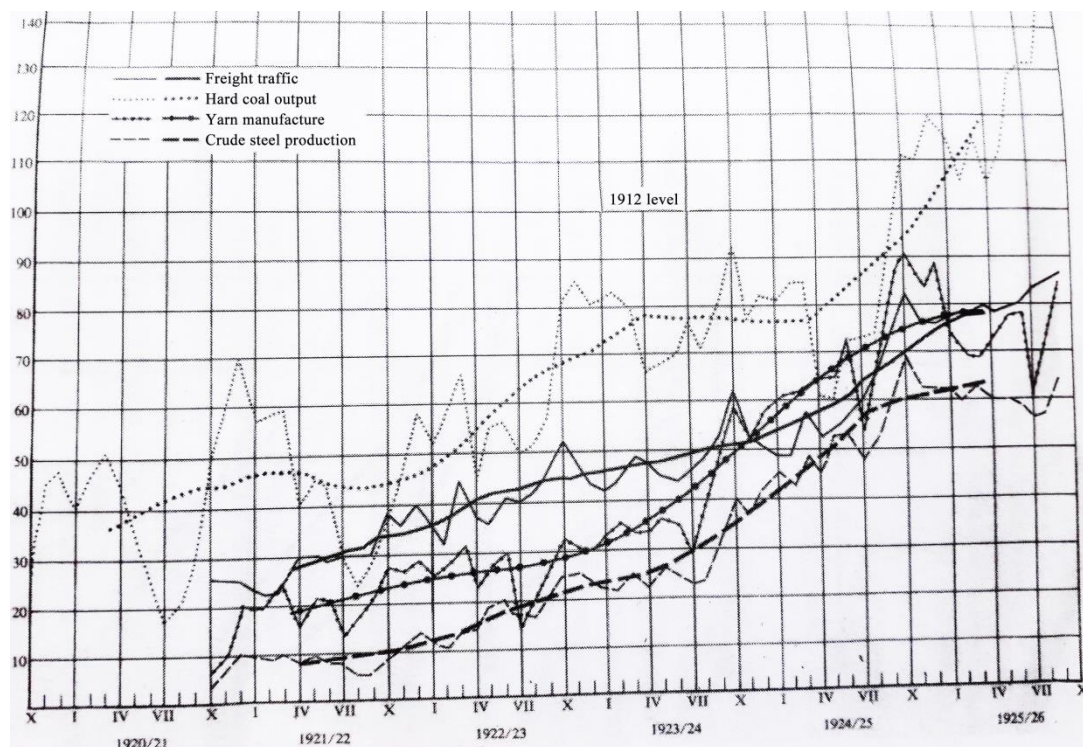
⁴⁰ The level value is captured by the parameter A in the equations.

⁴¹ An increase in labor productivity usually happens due to technological innovation, and Bazarov used this explanation. However, generally speaking, it could be not only an improvement in technologies, but also any other positive improvement of economic environment that could cause a labor productivity shift.

⁴² The full registration of the volume of industrial output for 1920-1921 was not available.

Bazarov supposed that if Gosplan had used the formula (8), the predicted growth would account for approximately 60% [Bazarov, 2014, vol. 2: 138]. Moreover, he gathered some statistics, illustrated in the graph below, to demonstrate that the formula (8) could be somehow helpful for the planification process. The graph shows the dynamics of the volume of hard coal output (six years data), yarn manufacture and crude steel production (five years data), and railroad freight traffic as an indicator characterizing the dynamics of the whole national economy (5 years data). The thin lines are used for the empirical curves, and the thick ones – for the curves obtained by calculating twelve-months moving average.

Figure 4. The structure of the recovery process.



Source: Bazarov, 2014, vol. 2, p. 141.

Bazarov claimed that in coal mining and freight traffic the real dynamics almost coincided that predicted by the hypothesis (recall the graph from the figure 2). In yarn manufacture the reality stayed ahead of the hypothesis (however there still was a slowdown in 1925-1926). As for the steel production, the hypothetical dynamics was even farther from the reality, the latter significantly outperforming the former⁴³. Later in the Capitalist Cycles Bazarov also explains how the specifics of metallurgy and its role in the Soviet economy at its early stages could influence its dynamics.

⁴³ This difference becomes more obvious after the analysis of the extrapolation of the graph from the figure 4. Bazarov suggested the way the moving average would continue changing in the second half of the year 1925-1926 [Bazarov, 2014, vol.2: 142], basing the suggestion on the preliminary (not official yet) data available at Gosplan.

Nevertheless, the form of the curves resulting from the scatter plot of the moving averages for all the industries is similar to the curve representing the formula (8).

Bazarov also offered a verbal explanation of why the restauration process of the Soviet economy could follow the same path and go at the same pace as the process corresponding to the autocatalytic reaction. As it has been described in the previous chapter, in an autocatalytic reaction each molecule stimulates the creation of the new molecules of the same structure. The speed of this process is, on the one hand, proportional to the number of newly emerged molecules, and on the other hand, similarly to the first case considered earlier, stays proportional to the number of molecules still not involved in the reaction. Thus, at first reaction is going at a slow pace, which increases with the number of molecules reacted. At a certain point, when this number is equal to the number of molecules that still had not reacted, the pace stops accelerating and stays constant for a moment. Later, with the decrease in the number of non-reacted molecules, the reaction slows down until the point when all the molecules react. The same change in the speed of the restauration process Bazarov explained with the following logic: the process started when the Soviet economy was exhausted because of the wars and the Policy of Military Communism, and by the time the New Economic Policy was announced, Soviet industry “presented an image, precisely the opposite from the main rule of proper management: right person in the right workplace” [Bazarov, 2014, vol. 2: 136]. Thus, the very first organizational steps were the most difficult, and the growth of the industrial output in the very beginning of the recovery was slow. Then, every goal achieved was helping the further progress, so the more enterprises were brought back to life, put in order, and modernized, the faster the recovery was advancing. Afterwards, when the industries started getting closer to the point of their maximal potential production, the growth slowed down.

An argument against the possibility of the quantitative measurement of social phenomena was their complexity. Bazarov managed to turn it to their advantage, when giving comments about his first model resulted in the equation (6). As it has been mentioned, the fact of not complete randomness of consumers’ movement on the market convinced him of the validity of the model. Since consumers’ mind is complex, and they are not just wandering around the market till stumbling upon the good they were looking for (like molecules in a solution would do), they move in certain directions with the relatively unchanged speed. Bazarov concluded that “the complexity of social processes facilitates their investigation, makes it possible to apply statistical regularities even to small samples that would give an image of complete chaos in physics and chemistry” [Bazarov, 2014, vol. 2: 99]. Thus, in his opinion, if the equation (6) successfully described the way the chemical reaction occurred, it would describe the market saturation process (under above mentioned assumptions) with more precision even if the number of observations was small.

Contributing to the development of his country had always been Bazarov's objective, and he was doing it through his work in Gosplan, trying to build the theory that could lead the planification in the tight direction. Advocating the quantification of the social phenomena, Bazarov viewed analogic modelling as a justified scientific method for the cases where the structure of the natural process was identical to that of the social process that needed to be modeled. Thus, Bazarov's justification of using analogies in the modelling of social processes, in particular, the restauration process, was based on, firstly, careful analysis of the properties of the target process (social one) and the source of analogy (natural process). In case every stage of one process had a correspondence in the structure of another process, the scientific methods could be transferred from one process to another. Moreover, the less random nature of social processes made Bazarov believe that the models, working for more random natural cases, would predict the outcome with even more precision for economic processes. In order to convince his readers and the authorities, Bazarov demonstrated some statistical data and proved it to be in line with his theoretical inference.

2.3. Perceptions of Bazarov's model in USSR

The first section of the present work gave an idea of the factors that could affect the scientific research of Vladimir Bazarov, mainly his work on the restauration process model. The agency where he was serving played an important role in that work. After the book *Capitalist Cycles* was published, Gosplan came forward again, to decide the fate of the model, built to provide theoretical support to its research officers. Further investigation of how the restauration model was perceived by the public (Bazarov's colleagues, his opponents, and the authorities) will be based mainly on Gosplan periodical *Planovoye Khozyajstvo* (Planned economy). It was an official politico-economic journal of the planning committee⁴⁴, where one could find the most relevant publications on the planification methodology, its ideological foundations and plenty of the USSR statistics. The issues of *Planovoye Khozyajstvo* published within the period from 1928 to 1931 reveal changing attitudes towards Bazarov and his work. Before the end of 1928 there were still some positive comments on Bazarov's ideas in Gosplan periodical. For instance, A.S. Gordon debating over the report of N.A. Kovalevsky⁴⁵ shared his opinion that "those curves that V.A. Bazarov designs and which, as they seem to me, are the attempts to determine the direction and resistance

⁴⁴ The first issue was published in 1923 under the name *Gosplan Bulletins*. The next year it was published under the name *Planned economy. Bulletins of the USSR State Planning Committee*, and starting from 1925 the title was shortened to *Planned economy*. Vladimir Bazarov was its editor-in chief (together with M. Markovich) from June to December of 1924.

⁴⁵ N.A. Kovalevsky's report was a part of the panel on the methodology of the general plan. Eleven Gosplan workers, including Bazarov and Groman presented their feedback on Kovalevsky's speech [Krzhizhanovsky et al, 1928: 134-186].

of social masses, these curves can be very useful” [Krzhizhanovsky et al, 1928: 178]. Gordon also emphasized that Bazarov’s models and corresponding growth curves were not describing the path the planned economy would follow. On the contrary, in his understanding, they characterized the resistance of the social masses, the resistance that had to be overcome in order to achieve the goal of the plan. Bazarov himself admitted that his two models elaborated in *Capitalist Cycles* were only a rough approximation, requiring way more research in order to be completed and become solid and reliable (see subsection 2.2.2). Thus, Gordon’s comment should be interpreted as a positive feedback on Bazarov’s models. However, Kovalevsky in his opening report followed by the debates (that included Gordon’s speech) was more critical of Bazarov. He did not support Bazarov’s idea of approaching the planification in the agricultural sector genetically [Krzhizhanovsky et al, 1928: 138] and did not accept the theoretical value of the growth curves derived by Bazarov [ibid, 140]. Nevertheless, the general tone of the speech is more neutral than negative. Together with the critical comments Kovalevsky highlighted that “in a dispute about the primacy of the teleological versus genetic approach, V.A. [Bazarov] managed to take the most correct position” [ibid], meaning that Bazarov understood the importance of both. In the same year one could find also some negative reviews in the issues of *Planovoye Khozyajstvo*. In the August issue R.E. Vaisberg⁴⁶ accused Bazarov of the wrong understanding of Marx’s views on productive labor. Disagreeing with the Communist Party’s interpretation of Marx was seen malevolent because that and only that interpretation was accepted as a part of the USSR ideology. Vaisberg claimed that Bazarov, trying to clarify Marx’s position on productive labor, changed it beyond all recognition and that he, Bazarov, “already 30 years ago declared holy war on “material bias”, found by him in none other than Marx’s works”⁴⁷ [Vaisberg, 1928: 170]. What Bazarov classified as productive labor is out of the scope of the present paper, but the fact that he was publicly criticized for the “misrepresentation” of Marx’s ideas could negatively influence the perception of his other works.

Starting from 1929 Bazarov faced aggressive criticism, caused mainly by misunderstanding or incomplete understanding of his ideas. Negative attitude towards him could also be connected with the so-called Great Break (or Great Turn)⁴⁸, the radical change in the economic policy in 1928/29. The Communist Party decided to replace the New Economic Policy by the accelerated

⁴⁶ Vaisberg was Bazarov’s famous opponent, and criticized almost all of his ideas as it will be demonstrated in this chapter.

⁴⁷ Later in the text of his article Vaisberg compared Bazarov to another Gosplan worker A. Abolin, emphasizing Bazarov’s courage. He said: “The difference between you is that you are cowardly and Bazarov is braver. Bazarov speaks out against Marx in no uncertain terms, and you cannot do that, so you formally oppose me, and not Marx” [Vaisberg, 1928: 171].

⁴⁸ The term came from the title of Joseph Stalin’s article “Year of the Great Turn” [Stalin, 1929b].

collectivization and industrialization. As it was already mentioned in Bazarov's intellectual biography, in the late 1920s the government tried to blame the leading NEP economists for all the economic problems, justifying also the turn to the new policy. Belykh and Mau in their introductory article to the collection of Bazarov's works claimed that "already in 1928 came the search for "pests" who were supposed to take responsibility for all the mistakes of Party's economic policy" [Bazarov, 2014, vol. 1: 69]. Bazarov was attacked on two main grounds: his belief in the primacy of genetic methodology⁴⁹ and his concept of the slowing growth pace (S-shaped growth curve) during the restauration process, the latter being the biggest issue for the supporters of the forced industrialization. In 1929 I.A. Byaly examined the ideas presented in *Capitalist Cycles* and concluded that "Bazarov's defense of the slowing pace theory is based on his theory of reproduction and crises and at the same time represents the development of this theory. But as well as the theory itself, its development carries on itself a bright stamp of primitivism and vulgarization" [Byaly, 1929: 123]. Byaly claimed that Bazarov's idea of S-shaped growth curve was "fundamentally erroneous because it was based on one-sided consideration of factors from the sphere of the productive forces only" [ibid], implying that Bazarov ignored the importance of industrial relations. In the end of the analysis Byaly even accused Bazarov of evolving a "beautiful theory hostile to the Soviet system" [ibid, 124]. Many concepts mentioned by Bazarov in his book *Capitalist Cycles* and other articles were mixed up in this critical article, and the author sometimes allowed himself make comments, revealing that he did not read Bazarov carefully or did not take his time to completely understand what the latter was trying to say. For instance, Byaly stated that Bazarov "completely ignored the significance of the plan" [ibid, 122]. This was only the beginning of the public condemnation of Bazarov and the group of economists, usually referred to as "Groman-Bazarov-Kondratiev". Above mentioned R.E. Vaisberg explained the main claims against these economists: "Bazarov, Groman, Kondratiev and other representatives of bourgeois thought in planification shout the loudest about our disproportions, gaps, rough edges, bottlenecks, etc. The only thing they see is that the situation is bad, everything is slipping through our fingers" [Vaisberg, 1930: 24]. In the beginning of 1930 Bazarov was already classified by Gosplan's leading economists (Vaisberg was a member of Gosplan Presidium and also an editor of *Planovoye Khozyajstvo*) as a "representative of bourgeois thought in planification". This label undoubtedly affected Bazarov's image and provided grounds for his further prosecution and arrest. Later, the reactions on the ideological component of Bazarov's

⁴⁹ As it has been explained, Bazarov admitted the importance of both genetic and teleological approaches to the planification, however, his opponents were referring to some phrases taken out of context to blame him in not committing to the directives and not believing in the capacities of the Soviet industry.

research were numerous⁵⁰. This sounds ludicrous since he himself repeatedly emphasized ideological neutrality of his research. Vaisberg, however, claimed that “Bazarov's methodology, allegedly apolitical, but in fact extremely hostile to socialist construction is fundamentally rotten” [ibid, 38]. In the context of ideological critique Bazarov was also blamed for the assimilation of the Soviet system to a capitalist. In an extremely judgmental article “About the malicious planification theory” M. Ragolsky was proving that “Bazarov not just draw an analogy with capitalism but equated our system to it” [Ragolsky, 1930: 72], giving a quote from *Capitalist Cycles* (Bazarov's words given in italics): “*In both cases (that is, in our Soviet system and under capitalism. M. R.), the dynamics should be not uniformly slowing, but cyclical*” ... (p. 102). The only difference is that due to the difference of our credit system from the capitalist one, we will not have an acute crisis” [ibid]. In fact, this phrase was taken out of context. Bazarov was saying: “the dynamics of the restauration process in its formal structure is similar to that of the “autocatalytic” reaction, and also to the dynamics of capitalist industry during the period it moves from the depression to the expansion phase through the technical reconstruction that increases labor productivity (see chapters IV and V). *In both the dynamics should be not uniformly slowing, but cyclical*, – however, there is one very significant distinction” [Bazarov, 2014, vol. 2: 137]. Further he explained that since Soviet government credit system was fundamentally different from private capitalist one, in the Soviet economy there would be no overheating usually caused by free access to loans in capitalist economies. Thus, Ragolsky did not mention that Bazarov was talking about one specific process, not the whole dynamics of the Soviet economy, and he definitely underestimated the role of the difference in credit systems. Bazarov explained that there could be no crisis in the Soviet economy (“restoration cycle should more or less smoothly bring production to a new level without a crisis in the end” [ibid]), not just the absence of “acute crisis”. Ragolsky could disagree with Bazarov's view of the restauration process and his theory, but accusing the latter of equating the Soviet system with a capitalist was quite ignorant from his part. Later in his article Ragolsky even stated that Bazarov denied advantages of the Soviet economy over a capitalist one and used it (absence of advantage) as an assumption to justify the slowing pace model [Ragolsky, 1930: 83]. Probably, the fact that in the end of the restauration process the model predicted the growth pace to slow down was the most disturbing for Bazarov's detractors. Some of them said that in economic literature of that time “Bazarov (as a planning worker) was famous mainly for his slowing pace theory” [Boyarsky, 1930: 159]. The S-shape curve and the whole model were considered as an attempt to “hold down the pace of growth” [Kviring, 1930:11]. Gosplan officers who shared this opinion clearly ignored the fact that Bazarov tried to model the

⁵⁰ Especially the last issues (9th-12th) of *Planovoye Khozyajstvo* in 1930 were full of accusations like “pest”, “menshevik”, “bourgeois economist”, “enemy of the Soviet Union”, “troubled theoretician”.

restauration process only, not the dynamics of the Soviet economy in the long run. Strong dissatisfaction with the model predicting S-shape growth curve was expressed not only by economist, but also by the Communist Party leadership. I. Stalin in his “Political report of the Central Committee to the sixteenth All-Union Communist (Bolshevik) Party Congress” [Stalin, 2018: 30-120] originally published in 1930 on the 27th of June stated: “There is a theory according to which high pace of development is permissible only during the restoration period, and with the transition to the reconstructive period the growth rates should decrease sharply from year to year. This theory is called the “concave curve” theory. This theory is justifying our underdevelopment. It has nothing to do neither with Marxism nor with Leninism. It is a bourgeois theory, designed to consolidate the backwardness of our country” [Stalin, 2018: 105]. After this kind of review coming from Stalin himself, Bazarov’s theory had to be buried. Stalin also demonstrated that the socialist reality did not confirm the predictions of the model: “In fact, the growth rate of state industry output was in 1926-27 constituted for 19.7%; in 1927/28 – 26.3%; in 1928/29 – 24.3%; in 1929/30 – 32%, and in 1930/31 it will be 47%” [ibid]. These data could refute Bazarov’s theory but only if the real restauration process (not the planned one) had strict time limits, so that it would end in 1930. There is another problem with Stalin’s statistical argument: his figure for the year 1929/30. Even in his extremely critical article Ragolsky gave a growth rate of 25% for this year. One would expect Ragolsky to give the same number as Stalin, it would be a better argument to prove Bazarov wrong. This inconsistency is quite odd, especially taking into account that Ragolsky’s article was published later than Stalin’s speech, in November 1930⁵¹.

The negative comments and false accusations became very common, the surname “Bazarov” was found in the issue number 10-11 of the 1930 *Planovoye Khozyajstvo* more than 250 times, and each time Bazarov was brought up to be criticized. At the same time, there are not many articles, providing the analysis of Bazarov’s special analogic methodology. Some short comments show that Bazarov’s method was not taken seriously. E. Kolman characterized analogic reasoning as a “mechanical transferring of the methods of natural sciences into economics” [Kolman, 1928: 181], meaning that it was not scientifically justified. In general, Kolman claimed to be in favor of using the means of physics and chemistry in economic investigations, specifically, in the studies of economic equilibrium. In fact, he was in favor of using math in economics⁵². In his article Kolman

⁵¹ Even more odd it becomes after we read the article by Belykh and Mau where they testify that actual growth rates for the last three years of the first five-years planned period (1930, 1931, 1932) reached only 20.5%, 14.7% and 5.5% correspondingly [Bazarov, 2014, vol. 1: 74].

⁵² For E. Kolman, as for many of his and Bazarov’s contemporaries, the means of physics and chemistry meant mathematical methods. There was a clear distinction between social and natural sciences and their methodologies: natural sciences used mathematical methods, and social sciences used mainly descriptive methods and sometimes statistics. Bazarov mentioned this separation in *Capitalist Cycles*: “the application of the formal quantitative analysis

suggested a formal mathematical system of economic performance indicators characterizing internal processes of the transition from capitalist economy to socialist (and back). The article contained the elements of mathematical research, such as systems of linear differential equations. At the same time, Kolman claimed that there was “no need to “complement” Marx’s concept, not even with the naturalistic assumptions about the essence of market exchange, made by V. Bazarov in his book “Capitalist Cycles”, assumptions that deprived this most interesting work of scientific value” [ibid]. Nevertheless, Kolman’s review was an example of constructive criticism of Bazarov’s modelling, probably because it was published in 1928 before the main persecution of Bazarov-Groman group started. More evidence proving that Bazarov’s methodology was not considered as a serious scientific approach from 1930 is much more insulting. M. Ragolsky in the article “About the malicious planification theory”, already quoted before, stated that “Bazarov breaks the record of mechanical understanding of social phenomena!” [Ragolsky, 1930: 68]. The context proves that Ragolsky meant it in a bad way, intending that Bazarov’s analogies did not make sense. Further, he expressed his opinion quite concisely, putting just an exclamation mark after a quote from *Capitalist Cycles* (again, Bazarov’s words given in italics): “*the dynamics of the recovery process in its formal structure is similar to that of the “autocatalytic” reaction (!)*” [Ragolsky, 1930: 71].

By the end of 1930 the name Bazarov was strongly associated with “Menshevik-pest” [Heinman, 1930:216]. However, even his opponents admitted that “Bazarov is one of the most educated, if not the most educated of the pests” [Boyarsky, 1930: 159]. After the “Menshevik process” of 1931 Bazarov and his ideal were glossed over in official Gosplan literature. Belykh states that his works were not completely forgotten, referring to Kondratiev’s research in Suzdal [Bazarov, 2014, vol. 1: 77]. Previously, in subsection 2.2.2 it was already mentioned that Kondratiev requested Bazarov’s book *Capitalist Cycles* while being in exile. Belykh believes that “in his model of economic dynamics, the differential equation proposed by Bazarov was used to describe the law of variation of most variables” [ibid]. Gosplan officials, however, never consulted with Bazarov’s works anymore. Together with the leadership of the Communist Party they set a course for accelerated forced industrialization, and the growth rate of Soviet economy was supposed to forever follow “Bolshevik rising curve” [Stalin, 2018: 105] and not Bazarov’s S-shape curve.

to social studies, so largely developed in the twentieth century due to the progress of mathematical statistics, is still too limited” [Bazarov, 2014, vol. 2: 55].

Section 3. Concluding remarks

3.1. Recent feedback

Analyzing Model 2 from the economic point of view Andrei Belykh notes that “Bazarov's concept was an interesting scientific hypothesis, but in the 1920s it had a simplified interpretation” [Belykh, 2011: 67]. As it was demonstrated in the previous section, he was considered just as a proponent of slowing growth pace theory. The majority of Bazarov’s colleagues claimed that he was predicting an inevitable slowdown for the Soviet economy. However, the figure 2 proves that it was a wrong conclusion since the slowdown only happened while approaching a new level of labor productivity (in Bazarov’s equations it is a variable A that characterized a certain level). At the same time, a new boost in labor productivity would initiate a new restauration process, so the economy would grow again.

Thus, the growth is described by an S-shaped curve. Reconstruction, caused by the introduction of new technology makes it possible to achieve a new level of production. When approaching it, the speed of the process slows down. Belykh concludes that “development is a consistent acceleration and attenuation of growth rates, described by S-curves, and the size limits of output are determined by the level of technology” [ibid]. He stated that it would be wrong to include Bazarov in the authors the diffusion of innovations theory, however, the important role of technologies in the dynamics of the national economy were first noted in his works.

Speaking of Bazarov’s modelling Belykh points out that he “allowed inaccurate use of the concepts of pace and speed. The speed is determined by the first derivative of the function, and the pace is set by the ratio of the speed to the value of the function” [ibid]. In fact, what Bazarov intended by “pace” or “growth rate” was the speed of the restauration process. Thus, it was the speed that was first increasing and then decreasing. The pace was decreasing all along the process. To get the equation of the pace the formula 4:

$$\frac{\partial x}{\partial t} = k \times x \times (A - x)$$

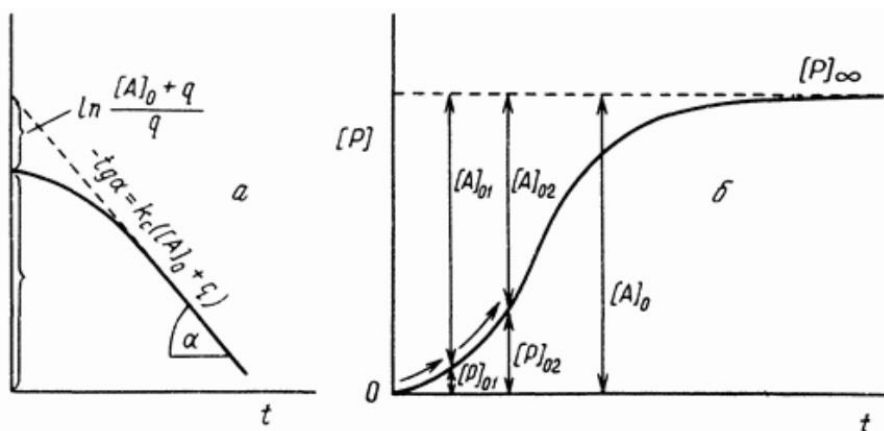
has to be modified as follows:

$$\frac{\partial x}{\partial t} \div x = k \times (A - x) \quad (5)$$

It is clear that with the increase in x the pace decreases. This is actually a well-known fact in the theory of autocatalytic reactions. One can find the illustrations in any chemistry textbook. In a figure below the left graph captures the pace of the reaction, and the right one illustrates its dynamics (the number of reacted molecules depending on time). The pace here is determined by a logarithmic function. The speed would look like a concave parabolic function. Its vertex would

have the same time coordinate as the point where the reaction dynamics function changes its form from convex to concave.

Figure 5. First order autocatalytic reaction.



Source: Schmid, Sapunov, 1985, p. 76.

3.2. Conclusions

Vladimir Bazarov had a rare largeness of mind. His ideas were, undoubtedly, very sophisticated for his times and might be useful even now. Nobel Prize winner Vasily Leontyev named the mathematical theory of economic growth developed by Bazarov among the most outstanding results of Soviet economics [Leontyev, 1989]. He was able to work both on practical tasks (for example, building of annual plans and the first long-term plan) and theoretical issues (development of the methodology of long-term planification, mathematical modelling), had excellent skills in statistics [Belykh, 2011: 67], and suggested to widely use analogies as a means of scientific discovery in economics. The features of analogic modelling in Bazarov's works became a subject of the present study. The restauration process model presented in the book *Capitalist Cycles and the Restoration Process of the USSR Economy* was taken as an example of an analogy-based model, built by Bazarov.

It has been shown that there were many factors that affected Bazarov's work on the model. Increasing interest to quantification in economics in 1920s, publication of inter-disciplinary investigations, chemistry education that he received, his friends and colleagues, his work in Gosplan and the practical problems he had to solve working there – all this shaped his methodology. Bazarov modeled the restauration process of the Soviet economy in the image of an autocatalytic reaction, justifying this analogy by stating that mechanism of the recovery of the economy after the period of War Communism, external and internal wars had the same organizational structure as a first order autocatalytic reaction. Bazarov was admitting that the model was far from being perfect, however could still be of some use for Gosplan.

The model was negatively received by the majority of Bazarov's colleagues in Gosplan since it predicted decreasing growth rates (actually, decreasing speed). However, the fact that this model was applicable only to the restauration process and that technological innovations allowed economy to grow steadily was ignored. Belykh also points out that Bazarov's methodology was misinterpreted, and he was believed to advocate purely genetic approach and forecasting based on extrapolation of past trends [ibid, 68]. Subsection 2.3 proved that Bazarov's opponents accused him of underestimating the power of teleological approach, i.e. directives from the government, and promoting genetic planning that predicted the decreasing growth.

We believe that Bazarov's restauration process model is an example of a successful use of analogies as a means of scientific discovery in economics. Even if its practical value could be questioned nowadays, the model might still be considered of theoretical interest, especially because it is an example of the use of analogies with chemistry – a new type of analogies in the Russian Soviet science of Bazarov's time.

Bibliography

- Ayres, R. U., Nair, I. (1984). Thermodynamics and economics. // *Physics Today*. No. 37. Pages 62-71.
- Barnett, V. (1992). *At the margins of the market: conceptions of the market and market economics in Soviet economic theory during the new economic policy, 1921-1929*. (PhD thesis, University of Glasgow)
- Bazarov V.A. (1899) *Trud proizvoditel'nyj i trud, obrazuyushchij cennost'* [Productive labor and value creating labor]. Saint-Petersburg, izdatel'stvo S.Dorovatovskogo i A.Charushnikova.
- Bazarov V.A. (1923). *K metodologii izucheniya denezhnoj emissii* [To the methodology of money emission study] // *Vestnik kommunisticheskoy akademii*. Book 4. Pages 28-100.
- Bazarov, V.A. (1917). Marksistskoye otnosheniye k vosstaniyu. [Marxist attitude to the revolt]. // *Novaya Zhizn*. October, 17 (30).
- Bazarov, V.A. (1924). *K metodologii perspektivnogo planirovaniya* [To the methodology of long-term planification]. Moscow: Gosplan.
- Bazarov, V.A. (1926a). *O metodologii postroyeniya perspektivnykh planov* [About the methodology of long-term plans building] // *Planovoye khozyajstvo*. No. 7. Pages 7-21. Moscow.
- Bazarov, V.A. (1926b). "Kriviye razvitiya" kapitalisticheskogo i sovetского khozyajstva [The "Curves of development" of the capitalist and Soviet economy] // *Planovoye Khozyajstvo*. No. 4, pages 87-119; No. 5, pages 71-90; No. 6, pages 51-94.
- Bazarov, V.A. (1927). *Kapitalisticheskiye cikly i vosstanovitel'nyy process hozyajstva SSSR*. [Capitalist cycles and the restoration process of the USSR economy]. Moscow: Gosizdat.
- Bazarov, V.A. (1928). *Prinzipy postroyeniya perspektivnogo plana* [Principles of long-term plan building] // *Planovoye Khozyajstvo*. No. 2. Pages 38-63. Moscow.
- Bazarov, V.A. (2014). *Bazarov. Selected works* // ed. by A.A. Belykh. 2 volumes. Moscow: Delo.
- Belykh, A.A. (2011). *Istoriya Rossijskikh ekonomiko-matematicheskikh issledovanij. Pervyye sto let*. [The history of Russian economic-mathematical research. The first one hundred years]. 3rd edition. Moscow: LKI publishing house.
- Blohin N. (2006) *Filosofskaya publicistika V.A. Bazarov i russkij Marxism nachala XX veka* [Philosophical publications of V.A. Bazarov and Russian Marxism in the beginning of the XX century]. Moscow: Vestnik Moskovskogo universiteta. Series 6: History. No. 4.
- Boyarsky, A. (1930). O teorii zatuhayushchego tempa razvitiya sel'skogo hozyajstva [About the slowing pace theory of agriculture development]. // *Planovoye Khozyajstvo*. No. 10-11. Moscow.

- Bukharin, N.I. (1922). *Teoriya Istoricheskogo materializma* [The theory of historical materialism]. Moscow.
- Byaly, I.A. (1929). Balans, krizisy, rol' sub'ektivnyh i ob'ektivnyh faktorov [Balance, crises, the role of subjective and objective factors]. // *Planovoye Khozyajstvo*. No. 9. Pages 111-130. Moscow.
- Chronics of the September, 3rd (1930) // *Izvestia*. September 3. Moscow.
- Despres, L (1980). *Une theorie sovietique de l'hyperinflation : l'economie d'emission 1918-1924*. [The Soviet theory of hyperinflation: the economy of emission 1918-1924]. Universite de Paris I Pantheon Sorbonne : centre d'economie internationale des pays socialistes : Groupe de recherche sur la theorie de l'economie socialiste. [PhD thesis, University of Paris 1 Pantheon Sorbonne: center of the international economics of the socialist countries; socialist economic theory research group].
- Duhem, P. (1906). *La théorie physique: son objet – sa structure*. Retrieved from <https://books.openedition.org/enseditions/6915>
- Ehrlich, A. (1960). *The Soviet Industrialization Debate, 1924-1928*. Cambridge: Cambridge University Press.
- Fechner, G.T. (1966). *Elements of Psychophysics*. Vol. 1. (H.E. Adler, Trans.). New York, NY: Holt, Rinehart and Winston. Retrieved from <https://trove.nla.gov.au/work/16448924>
- Georgescu-Roegen, N. (1971). *The Entropy Law and the Economic Process*. Cambridge, Massachusetts: Harvard University Press. ISBN 978-0674257801.
- Gosplan (1926). Kontrol'niye cifry narodnogo khozyajstva na 1925/1926 god [Control numbers of the national economy for the years 1925/1926]. // *Planovoye Khozyajstvo*. Moscow.
- Heinman, S. (1930). Problemy truda [Labor issues]. // *Planovoye Khozyajstvo*. No. 12. Moscow.
- Hesse, M. (1966). *Models and analogies in science*. Notre Dame, Indiana: University of Notre Dame Press. Library of Congress Catalog Card Number 66-14364.
- Ilyin Vl. (1909). *Materialism i empiriocriticism. Kriticheskiye zametki ob odnoj reakcionnoj filosofii*. [Materialism and empirio-criticism. Critical notes on one reactionary philosophy]. Moscow. M.: Zveno.
- King, F. W. (1994) *The political and economic thought of Vladimir Aleksandrovich Bazarov (1874-1939)*. PhD thesis, University of East Anglia.
- Klyukin, P.N. (2014) *Evristicheskoye znachenie principa vozvratnoj tradicii (na primere tvorcheskogo naslediya N.D. Kondratieva)* [Heuristic meaning of the principle of recurrent tradition (on the example of N.D. Kondratiev legacy) // *N.D. Kondratiev legacy and modern times*. Ed. by P.N. Klyukin. Saint-Petersburg: Alateya.

- Kolman, E. (1928). O sisteme pokazateley sovetsskoy ekonomiki [About the system of Soviet economy indicators]. // *Planovoye Khozyajstvo*. No. 10. Moscow.
- Kondratiev, N.D., Oparin D.I. (1928). *Bol'shiye zikly kon'yunktury* [The Major Cycles of the Conjunction]. Moscow. M: Institute of economics RANION.
- Krzhizhanovsky, G.M., Kovalevsky, N.A. et al. (Eds.). (1928). *Planovoye Khozyajstvo* [Planned Economy]. No. 6. Moscow.
- Krzhizhanovsky, G.M., Kovalevsky, N.A. et al. (Eds.). (1929). *Planovoye Khozyajstvo* [Planned Economy]. No. 1. Moscow.
- Krzhizhanovsky, G.M., Kovalevsky, N.A. et al. (Eds.). (1930). *Planovoye Khozyajstvo* [Planned Economy]. No. 3. Moscow.
- Kviring, E. (1930). Zadachi osobogo kvartala [The tasks of a specific quarter]. // *Planovoye Khozyajstvo*. No. 9. Pages 5-18. Moscow.
- Lenin, V.I. (2017). *Polnoye sobraniye sochineniy* [Complete collection of works]. Vol. 5. [Google Books version]. Retrieved from https://books.google.fr/books?id=J1KjCwAAQBAJ&printsec=frontcover&vq=%D0%B0%D0%B3%D1%80%D0%B0%D1%80%D0%BD%D1%8B%D0%B9+%D0%B2%D0%BE%D0%BF%D1%80%D0%BE%D1%81&source=gbs_ge_summary_r&cad=0#v=onepage&q=%D0%B0%D0%B3%D1%80%D0%B0%D1%80%D0%BD%D1%8B%D0%B9%20%D0%B2%D0%BE%D0%BF%D1%80%D0%BE%D1%81&f=false
- Leontyev, V. (1989). Column // *Pravda*. February 27. No. 58 (25776).
- Mirowski, P. (1991). *More heat than light: economics as social physics, physics as nature's economics*. Cambridge University Press.
- Morgan, M.S. (1999). Learning from analogies // *Models as Mediators* (ed. by M.S. Morgan and M. Morrison). New York. NY: Cambridge University press.
- Nikitin, E.N. (2002). Filosof-collectivist [Philosopher-collectivist]. // *Bibliografia*. No. 4.
- Ostapenko, S.S. (1925) *Energetika gromads'kogo hospodaryuvaniya za 1913 ta 1923 roki* [Energetics of social economy for years 1913-1923]. Kharkiv: Derjavne Vidavnistvo Ukrainy.
- Prokopovich, G.A. (1926). Mehanicheskiye modeli kinetiki himicheskikh prozessov [Mechanical models of the kinetics of chemical processes] // *Ukrainskiy himicheskii zhurnal*. No. 2.
- Ragolsky, M. (1930). O vreditel'skoy teorii planirovaniya [About the malicious planification theory]. // *Planovoye Khozyajstvo*. No. 10-11. Moscow.
- Robertson, T. B. (1923). *The chemical basis of growth and senescence*. JB Lippincott Company.

- Schmidt, O.Y. (1923). Matematicheskiy zakon denezhnoy emissii [Mathematical law of money emission]. // Vestnik Kommunisticheskoy Akademii. No. 3. Pages 85-99. Discussion: pages 256-277.
- Shchukarev, A.N. (1925) Termodinamika i kinetika obshchestvennykh prozessov [Thermodynamics and kinetics of social processes] // *Nauka i tekhnika*. Odessa
- Stalin, I.V. (1929a) K voprosam agrarnoy politiki v SSSR [To the questions of agricultural policy in the USSR] // *Pravda*. December 29. No. 309.
- Stalin I.V. (1929b) God velikogo pereloma: K XII godovshchine oktyabrya [Year of the great break: towards the 12th anniversary of October]. // *Pravda*. No. 259. P. 235. Moscow.
- Stalin, I.V. (2018). *O problemakh gosudarstvennogo upravleniya. Iz vystupleniy na partijnykh i khozyajstvennykh meropriyatiyakh* [About the problems of public administration. From the statements at the Party events and economic meetings]. [Google Books version]. Retrieved from https://books.google.fr/books?id=CWplDwAAQBAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false
- Strumilin, S.G. (1927). Industrializatsiya SSSR i epigony narodnichestva [Industrialization of the USSR and the epigones of populism]. Moscow. M.: Gosizdat.
- Vaisberg R.E. (1928). Protiv vul'garshchiny i legkomysliya [Against vulgarity and levity]. // *Planovoye Khozyajstvo*. No. 8. Pages 165-188. Moscow.
- Vaisberg, R.E. (1930). Burzhuaizniye izvrashcheniya v oblasti planirovaniya [Bourgeois perversions in planification]. // *Planovoye Khozyajstvo*. No. 1. Pages 11-41. Moscow.
- Vaisberg, R.E. (1931). Desyat' let nepa i planovoy sistemy [Ten years of NEP and planned system]. // *Planovoye Khozyajstvo*. No. 2-3. Pages 3-17. Moscow.
- Schmid, R., Sapunov, V.N. (1985). *Neformal'naya kinetika. V poiskah putey himicheskikh reaktsiy* [Non-formal Kinetics - in Search for Chemical Reaction Pathways] (Translation into Russian edited by Belezkaya). Moscow. M.: Mir.