Appendix A – Prior Literature

1. Prior Literature on Nighttime Light Data

Many papers have discussed whether the nighttime light data could be good indicators of different economic forces, including urbanization, population growth, and GDP; some of them are related to Russia and other former Soviet states. Overall, the results show that the statistics of nighttime light data, especially the luminosity sum, perform well in revealing some macroeconomic information. However, such estimation suffers from a variety of problems. The first limitation is that its ability to approximation varies from setting to setting. Replacement and aging of satellites cause the inconsistency of night light data, so the data require value adjustments. Data also can be easily contaminated, causing inaccurate results when focusing on specific aspects, such as urbanization.

Extensive researchers have used the nighttime light data to detect the urbanization process in different countries or areas. Mellander et al. (2015) use nighttime light (NTL) data in Sweden and conclude that NTL data could be an excellent indicator of the urbanization process in OECD countries. While Stathakis et al. (2015) focus on Europe, they employ the sum of lights per region to capture the urbanization process, finding that different European regions have various urbanization patterns. Furthermore, Gao et al. (2015) use a Compounded Night Light Index (CNLI) to measure the urbanization level of different administration levels in China. They indicate that from 1992 to 2012, the urbanization levels increased dramatically, but the regional-level variants on development speed are also quite large, where the overall levels of eastern provinces experienced a much higher growth rate than western provinces (Gao et al., 2015). Also focusing on China, Yi et al. (2014) create an index based on the nighttime light data, called the urban light index (NLI), finding a strong link between NLI and urban space evolution. As for employing the nighttime light data in Russia, Fan et al. (2018) conclude that, even with the population decline after the dissolution of the USSR, Russian cities in

Asian areas experienced an increased urban light luminosity after calibration, showing that urban expansion happened in these places. In sum, nighttime light data appear to be an excellent resource to track city expansion and the urbanization process, but this estimation requires the inter-calibration of the dataset.

Although Mellander et al. (2015) claim that NTL data are useful for analyzing urban expansion and activities, they also argue that using these data to represent the aggregate economic output is problematic because after the income levels hit a certain threshold, rising earnings are unrelated to night light growth. Nevertheless, many researchers have tried to use NTL as a measure of economic development in lower- and middle-income countries. Eldridge et al. (2012) use NTL and population density data to develop a Night Light Development Index to measure spatial development patterns in different countries. They find out this index has strong correlations with the UN's Human Development Index, as well as the poverty rates at the country level (Elvidge et al., 2012). Sutton et al. (2007) try two methods to measure the GDP of China, India, Turkey, and the US in 2000, one using the sum of night light intensity; the other using a spatial analysis. Their results show that using the NTL data to measure GDP is crude, but that the results are statistically significant so that they claim such methods could be helpful to approach the actual economic situation of less developed economies (Sutton et al., 2007). Chen and Nordhaus (2001) also state that the luminosity could work as a good proxy of economic output for low income countries, especially for those with poorly statistical systems, while for other countries, the approximation is relatively limited.

As for Russia, Bennett and Smith (2017) show that lights are significant predictors of GDP, especially for places with huge corruption problems, but they also mention that such prediction might not be applicable during periods of depopulation, economic decline, and other types of reverse

development. In sum, using the NTL data to estimate the Gross Domestic Product (GDP) is a plausible and well-established approach, but the approximation ability of such measurement decreases along with the countries' development or during reverse development periods, as luminosity may not decline during stagnation eras.

In addition to urbanization and GDP, researchers have used the nighttime light data to estimate other economic and social indicators, including population density, urban population, population mobility, and electricity consumption. Zhuo et al. (2009) employ NTL data to estimate Chinese population density. Their results closely match to other studies of Chinese population density, indicating that NTL data could work as a good proxy of population distribution. However, using NTL data to measure the population density could be problematic because the results could be contaminated by those workplaces whose population density is low, but night light intensity is high (Elvidge et al., 1999). Based on the results from Huang et al. (2016), nighttime light data are significantly related to the urban populations, especially in countries with an ongoing urbanization process and a considerable inflow of city population.

Turning to other uses, Sheludekov and Starikova (2020) use nighttime light data to investigate the second home mobility in rural Russia, and they also checked the influence of COVID-19 on second home mobility. As for electric power consumption, Townsend and Bruce (2009) create an Overglow Removal Model, which could increase the spatial measurement accuracy of using NTL data to estimate electrical consumption. Their results also show that such measurement is limited to relatively large areas, such as at the region or country-level (Townsend & Bruce, 2009). In another example, Lu et al. (2019) use population and built-up areas to inter-calibrate the dataset, and adjust data yield a better relation in the electric power consumption at the province level.

As for NTL limitations, Henderson et al. (2011) distinguish two categories of problems. First, the association between NTL data and the economic output varies based on time and space; second, NTL data fail to ideally generate true night light because of satellite changes and aging, and the contamination of unwanted light (Henderson et al., 2011). They provide cases of the first limitation, including poor performance of estimating GDP during economic decline. Moreover, much research has been conducted to solve the second limitation, the changes and aging problem of satellites. Zhang et al. (2016) build a model, called the ridgeline sampling and regression model, to conduct inter-calibration work, and their country-level results indicate that such a method could help reduce the bias of nighttime light data in most cases. (Elvidge et al., 2009) use an alternate inter-calibration method in which they select a base area known for experiencing minimal change (Sicily), and a base year and a base satellite (F12199); they then adjust other data to the same range by scaling pixels. This paper also mentions methods of getting rid of gas flares, which is caused by remote petroleum production, because the flares contaminate the results by producing a high-level luminosity only tangentially related to economic development (Elvidge et al., 2009). Furthermore, when estimating the urbanization process, lights in the rural areas become noisy, and to deal with such a problem, setting an urban light threshold is an excellent solving method (Yi et al., 2014).

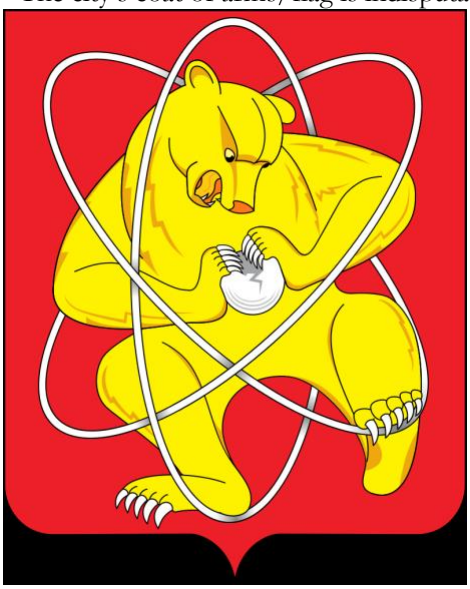
2. Russian-language Literature on Soviet Closed Cities and Their ZATO Successors

There is a substantial Russian-language literature on Soviet closed cities and their ZATO successors though, to our knowledge, none of it formally contrasts the fate of ZATO and matched non-ZATO cities. The only paper that touches on issues directly related to our work appears to be Dvoryadkina (2018), who focuses on the importance of federal government transfers to the survival of these cities. Her detailed analysis of a large number of these cities demonstrates the extreme

dependence on federal government transfers. By implication, independent entrepreneurial effects to date have been modest at best.

Rasskazchikova (2014, 2015) explores the evolution of Zheleznogorsk in Krasnoyarsk krai, which continued to grow rapidly until the end of the Soviet Union.[1] For our purposes, the papers usefully focus on late Soviet era growth – suggesting obvious explanatory variables that unfortunately are not available for all cities. Far more detailed discussions of closed atomic cities appear in the books of V.N. Kuznetsov, which in turn are summarized in Zaparii and Tolstikov (2018). Zverev and Karachkov (2018) offer a brief overview of closed cities in the Ural region to the west of Krasnoyarsk; a far more detailed version is given by Rod'kin (2009). Issues of architecture and physical layout for the closed atomic cities of Ozyorsk and Snezhinsk in Chelyabinsk Oblast receive attention from Mikhailova and Olen'kov (2019). Today, Snezhinsk is a "sister city" of Livermore, CA and portrays itself as a great place to live and work (snzadm.ru). Elsewhere, Konstantinova (2021) explores, but

[1] The city's coat of arms/flag is indisputably one of the most awesome ever designed:



Source: By Taejo - Own work, based on File:Flag_of_Zheleznogorsk.svg, Public Domain, https://commons.wikimedia.org/w/index.php?curid=26421416

only in abstract, general terms, the collective psychological trauma that ZATO cities experienced from loss of purpose with the collapse of the USSR.