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RUSSIA'S WARTIME ECONOMY: MEASURING REGIONAL INEQUALITIES FROM OUTER SPACE

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We are grateful for helpful comments and feedback received at the European Workshop on Political Macroeconomics (EWPM) in Lille; the Research Seminar Series at the University of Tartu and at the Bank of Finland (BOFIT); the IOS Regensburg Summer Academy in Tutzing, and the Economics of Global Interactions conference in Bari. Special thanks to Timothy Frye, Vladimir Kozlov, Aleksey Oshchepkov, and Alexander Plekhanov.

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ABSTRACT

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JEL CLASSIFICATION: F15, P25, R11.

KEYWORDS: Russia, regional and local inequalities, resilience, nighttime lights

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Abstract

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1 Introduction

The full-scale invasion of Ukraine in February 2022 was one of the largest economic shocks in Europe in recent decades. Ukraine experienced a dramatic contraction in economic activity, massive destruction of infrastructure, and the largest population displacement in Europe since World War II. The resulting output losses are in the tens of percent and damages amount to hundreds of billions of dollars (World Bank, 2025). Far less is known about the economic effects of the war on Russia, particularly those incurred due to disruptions to international trade, sanctions, and changes in market access. This is despite the indisputable fact that the conflict has fundamentally altered Russia's external economic linkages by tightening border regimes and reorienting trade flows, raising questions about how these shocks affected regional economic performance and inequality within the country.

Understanding the performance of Russia's economy after the 2022 invasion of Ukraine is crucial for assessing the impact of Western financial sanctions, the economy's capacity to absorb the costs of the war, and the uneven impact of the conflict across regions. This paper investigates these issues by addressing three key questions: First, how did economic activity in Russia evolve following the invasion? Second, what were the distributional consequences of the war at the regional level, that is, which cities or regions were adversely affected and which appear to have benefited? Third, is there evidence of a systematic reorientation of economic activity across Russia, away from countries that imposed sanctions and trade restrictions and towards more politically aligned third countries?

The evidence on the impact of the war on the Russian economy remains mixed and often ambiguous, largely depending on how economic activity is measured and which statistics are considered most reliable. On the one hand, official data from Rosstat support a narrative of economic resilience and stability, indicating a rapid recovery in 2023 (3.6% year-on-year growth), following a relatively mild contraction in the first year of the war, and continued growth in 2024 (4.3%). This explanation attributes economic disruptions primarily to Western sanctions while minimizing the domestic economic costs (Mamedov, 2025; Zhukov, 2025). Because this narrative relies heavily on official statistics, its credibility depends on the transparency and completeness of those data, both of which have been questioned by many, given Russia's autocratic political system and the broader uncertainty of a wartime economy. In particular, the official statistics may selectively obscure inflationary pressures, fiscal strains, and long-run growth deterioration

(Khudaykulova et al., 2022; SITE, 2024).

Research drawing on alternative data sources, on the other hand, suggests a different picture, with notable declines in GDP and overall economic activity (Audretsch et al., 2023; Schmidt and Sakhno, 2023; Astrov et al., 2024). Broader reviews further document significant macroeconomic and welfare losses that remain largely absent from the official accounts (Boungou and Yatié, 2022). This strategy of minimizing the adverse impacts of the war is systematic rather than incidental, extending beyond domestic communication to the way how Russia presents the state of its economy to neighboring countries and its perceived adversaries (Jamestown Foundation, 2022).

In line with the latter, our study adopts a skeptical view of the Russian economy's resilience. We rely on satellite-based nighttime lights (NTL) data to provide a transparent and spatially disaggregated alternative measure of Russia's economic activity in wartime. This allows us not only to assess the impact of the conflict on Russia's economy as a whole, but also to evaluate the distributional impacts at the sub-national level.

More specifically, the paper employs monthly satellite data (January 2012–January 2025) from NASA's Black Marble project, which is among the most comprehensive and highest-quality sources available compared to other satellite-based datasets of a similar kind (Gibson et al., 2020, 2025). The data are available at the pixel level and therefore need to be aggregated to the relevant geographical level to smooth-out noise present at the pixel level. Due to the unavailability of official city boundary data, we define urban boundaries by first web-scraping a comprehensive list of Russian cities from Wikipedia and then retrieving the corresponding city multipolygons from OpenStreetMap. By integrating these sources, we construct a novel city-level panel dataset of economy activity for Russia that enables us to track urban economic activity before and after the full-scale invasion of Ukraine started in 2022.[1]

Our analysis exploits the granularity of satellite data and documents that the war has significantly intensified spatial disparities within Russia. Although some cities and regions experienced short-lived or localized gains, the dominant trend is widespread slowdown of economic growth. Overall, our findings indicate that, after the invasion of Ukraine in 2022, the growth of economic activities, measured as the year-on-year monthly growth of the average intensity of NTL

[1]The dataset is available as the Russian Cities Spatial Dataset (`https://github.com/martinhulenyi/russian_cities`) at GitHub.

luminosity, in Russian cities decreased by approximately 4 percentage points.

We also find evidence of significant regional redistribution of economic activity. Russian cities closer to the EU experienced sharp declines in economic activity, whereas cities in eastern and southern Russia show moderate growth. This pattern is consistent with loss of market access to European markets and a subsequent reorientation of economic activity towards strengthening trade and investment ties with non-sanctioning countries. Moreover, we show that the economic impact of the war across cities is not determined solely by geographic location; it also varies with city size and administrative status. The most pronounced declines in economic activity following the invasion are observed in the smallest cities, followed by the largest cities, whereas the effect is negligible for mid-sized cities. We argue that these differences may be explained by variation in the economic structures of cities of different sizes and in their exposure to trade sanctions. Next, federal cities and oblasts experience the largest negative economic impact. In contrast, economic activity in republics, autonomous regions, and krais are largely unaffected by the invasion, which may be explained by war-related spending in these regions and the relatively small share of sanctioned firms.

Our study contributes to the ongoing discussion of Russia's economy, with a particular focus on its regional dimension. The closest papers to ours are Yushkov and Alexeev (2024) and Gorodnichenko et al. (2025). Gorodnichenko et al. (2025) primarily focuses on war-induced economic convergence in Russian regions, while Yushkov and Alexeev (2024) adopts a largely descriptive approach. Moreover, both studies rely on official government statistics, which raises concerns regarding data credibility. Our paper, by contrast, relies on alternative data sources and draws conclusions about the potential spatial restructuring of economic activity aimed at avoiding Western sanctions, through the relocation of economic activities to southern and southeastern regions.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature and political background. Section 3 describes the data. Section 4 presents the empirical strategy and estimation results. Section 5 explores mechanisms and heterogeneity analysis. Section 6 concludes.

2 Literature Review

The literature on the effects of Russia's full-scale invasion of Ukraine is extensive, examining the impact of the war on the Ukrainian economy, the effectiveness of financial and trade sanctions on Russia, the spillover effects on European countries and regions (Almazán-Gómez et al., 2024) and even the global economy (Liadze et al., 2023). In this section, we focus exclusively on studies that examine the Russian economy.

One strand of the literature examines the impact of Western sanctions on the Russian economy and Russia's response to these measures. Astrov et al. (2022) notes that the initial sanctions imposed on Russia were designed to target oligarchs, government officials, and key business figures with close ties to the Kremlin while trying to minimize the impact on ordinary citizens and the overall economic structure. As a result, the sanctions did not lead to a large-scale contraction of the aggregate economy. Instead, they aimed to create political and financial pressure on influential Russian figures.

More generally, Russia adopted a range of strategies to mitigate the impact of international sanctions. First, financial reserves were used to support large state-owned enterprises and strategic companies. Second, Russia increasingly turned to non-Western countries, particularly China, India, and other countries in Asia, the Middle East, and Africa, to build alternative trade and financial partnerships. This included redirecting energy exports to these regions and deepening economic cooperation. This helped compensate for the loss of the Western markets (Duong et al., 2024). Third, following its exclusion from international financing channels due to restricted access to SWIFT, the Russian government intervened by developing its own domestic financial infrastructure, thereby reducing reliance on Western financial systems. Russia also increased the use of China's Cross-Border Interbank Payment System (CIPS) for international transactions (Ahn and Ludema, 2020). Fourth, Russia found ways to continue to import restricted goods through intermediary countries, especially through neighboring states such as Kazakhstan, Kyrgyzstan, and Armenia. These countries acted as transit hubs, reexporting goods from Europe, the US, and Asia to Russia, bypassing direct sanctions (SITE, 2024). Fifth, the government enacted policies to stabilize its economy, such as capital controls, promoting domestic production to reduce import dependency, and offering subsidies to companies most affected by sanctions. This also included pushing for import substitution strategies, in which Russian companies were encouraged to develop local alternatives to previously imported goods (Davis et al.,

2022; Anisimova, 2025; Prokopenko, 2023). Lastly, the Russian economy has remained afloat due to increased military production and government spending.

The sanction-avoidance strategies were intended to minimize the adverse impact of the war on the Russian economy and citizenry. While official statistics suggest that these efforts have been effective, there is evidence that the reported economic performance may be overstated. For example, while Russia officially reports that inflation and unemployment remain low, independent sources present a more concerning picture (SITE, 2024). Furthermore, there have been instances when the Russian statistical agency reported certain statistics that President of Russia, Vladimir Putin, publicly contradicted (Lyndell, 2023). Such discrepancies have raised doubts about the reliability of the official data.

In a series of papers, Egorov et al. (2025, 2026) employ highly granular transaction-level data on international product shipments to examine the effects of export sanctions on Russia. They document that the sanctions had far-reaching adverse effects, reducing not only imports of directly sanctioned products but also a broad range of trade flows involving products that were never formally sanctioned, yet were nonetheless perceived to be at risk of future sanctions. Schmidt and Sakhno (2023), on the other hand, constructed a tracker of Russian domestic economic activity based on alternative monthly indicators that are independent of the official Russian statistical office. The tracker points to a further loss of momentum driven by stagnating real estate prices and lower business activity in recent months, which is not fully reflected in the official data releases. Using Google Trends data as an alternative measure of economic activity, Astrov et al. (2024) document some discrepancies between official statistics and these alternative indicators. This trend is not surprising, as using satellite data Martinez (2022) suggests that autocratic regimes often manipulate economic figures to present a more favorable outlook, potentially overstating GDP growth by up to 35%. NTL, a proxy for economic activity that is hard to manipulate, has become a critical tool for researchers to cross-verify such claims.

Fewer studies examine the impact of the war on the Russian economy at the subnational level. Yushkov and Alexeev (2024) and Gorodnichenko et al. (2025) document significant heterogeneity across regions and identify both winners and losers of the Russia's economic restructuring. The *winners* include regions that specialize in oil and gas extraction, military production, and those with high levels of mobilization.[2] In contrast, the *losers* include regions bordering Ukraine

[2]Mobilization has had a favorable impact on regions with high recruitment rates due to the sign-up bonuses received by contracted workers and due to compensation payments in case of death or injury (Solanko, 2024).

and those with industrial structures particularly exposed to sanctions. However, these results are again based on the official statistics. Alternatively, Behrens (2024) investigates the effects of the 2014 Russia-Ukraine conflict, focusing on how market access shifts due to border changes impacted economic performance in Russian border regions. Utilizing NTL data and geo-referenced plant-level data, the study finds that regions facing restricted market access experienced a significant reduction in economic activity, as reflected in a 43% lower NTL growth and a 6–12% decline in GDP growth. As uncertainty surrounding official Russian statistics has increased, the use of alternative data sources has become a priority for objectively evaluating the current state of the economy. This is precisely what our paper proposes.

3 Data

Remotely-sensed satellite NTL data have become an increasingly important tool in economic research, serving as a reliable proxy for economic growth (Henderson et al., 2012), urbanization (Puente-Ajovín et al., 2024), population (Düben and Krause, 2021), local economic activities (Wang and Xu, 2026), infrastructure development (Donaldson and Hornbeck, 2016), and regional inequality (Lessmann and Seidel, 2017). In contexts where traditional economic indicators such as the GDP and firm-level statistics are unavailable, delayed, or subject to political manipulation, NTL data offer an alternative: a high-frequency and objective measure of economic performance (Martinez, 2022). Russia presents an ideal case for using NTL data, as the reliability of official economic statistics has come under increasing scrutiny amid concerns of potential state-driven manipulation.

We use high-resolution NTL data from the NASA's Black Marble product, based on the Visible Infrared Imaging Radiometer Suite (VIIRS), to assess economic activity using luminosity measurements. The Black Marble dataset provides refined raw VIIRS NTL imagery at high spatial resolution, making it suitable for city-level economic analysis by removing ephemeral noise, such as wildfires, gas flares, and temporary lighting, and ensuring a more accurate representation of human and economic activities. Compared to older DMSP-OLS sensors, VIIRS provides higher radiometric sensitivity, reduced saturation in bright urban areas, and improved calibration, making it a more reliable data source for tracking long-term economic changes (Gibson et al., 2020).

We apply several pre-processing steps to the NTL data to ensure comparability over time.

First, we exclude data from May to August to avoid daylight interference. Second, we filter out observations affected by clouds or snow cover. Third, we adjust luminosity values to correct for sensor drift and orbital variations. Finally, we merge the pre-processed NTL light data with administrative boundary data, a step that is particularly challenging given the limited availability of reliable geospatial information in Russia.

Given the limited availability of official geospatial data for Russian cities, we, therefore, adopt an alternative approach. Specifically, we web-scrape a list of cities and towns from Wikipedia.[3] We then use the nominatimlite package (Hernangómez, 2026) to retrieve spatial boundaries for 1,082 cities. To ensure that the correct locations were returned, we append *"Russia"* to each city name in the query. In a small number of cases, we add the term "gorod" (city) to avoid retrieving the boundaries of higher-level administrative units rather than city-level polygons.[4] Finally, for cities sharing the same name but located in different regions, we replace *"Russia"* with the name of the corresponding federal subject in the query.[5] This provides a reliable geographic framework for collecting NTL data for Russian municipalities using the BlackMarbleR package (Marty and Stefanini Vicente, 2025).

4 Empirical Strategy and Results

Using monthly NTL data from January 2013 to January 2025 as an objective proxy for local economic activity, we estimate the impact of the full-scale invasion of Ukraine using a Regression Discontinuity Design in Time (RDDiT). The RDDiT framework, proposed by Hausman and Rapson (2018), is well-suited for scenarios with a single, simultaneous treatment event affecting all observational units and extensive pre- and post-treatment time-series data.

The RDDiT approach relies on the key assumption that, in the absence of the invasion, NTL would have evolved smoothly around the cutoff date. Consequently, any discontinuity observed at the cutoff can be attributed to the invasion. This design enables us to estimate the local average treatment effect of the invasion on economic activity while flexibly controlling for time trends and seasonal patterns.

[3]The list of cities and towns was obtained from the following Wikipedia page: https://archive.ph/IjKhf.
[4]This applies to Khabarovsk, Irkutsk, Magadan, Tomsk, Vologda, Stavropol, Lipetsk, and Onega.
[5]These cities are: Beryozovsky, Blagoveshchensk, Fokino, Guryevsk, Kirov, Kirovsk, Krasnoarmeysk, Krasnoslobodsk, Krasnoznamensk, Mikhaylovsk, Mirny, Nikolsk, Ozyorsk, Pavlovsk, Raduzhny, Sovetsk, Troitsk, Zarechny, Zelenogorsk, and Zheleznogorsk.

We conduct the analysis at the city, federal subject, and federal district levels.[6] To focus on short-run impacts and minimize bias from long-run structural changes, estimation is performed within a symmetric time window centered around the cutoff date of February 24, 2022.[7]

Our baseline specification is:

$$\Delta y_{it} = \beta \, \mathbf{1}\{t \geq T_0\} + \theta \, (t - T_0) + \gamma_{m(t)} + \alpha_i + u_{it}, \tag{1}$$

where Δy_{imt} denotes the year-on-year growth rate of the mean NTL for the city or federal subject (or district) i in the month t; $f(t \geq T_0)$ is an indicator equal to one after the invasion date T_0 (March 2022) and zero otherwise; $f(t - T_0)$ is a flexible function of time relative to the cutoff, capturing underlying trends; $\gamma_{m(t)}$ are month fixed effects controlling for seasonality; α_i are spatial unit fixed effects (cities, federal subjects, or federal districts); and u_{it} is the error term. Standard errors are clustered at the city or federal subject level to account for serial correlation. The coefficient of interest, β, measures the discontinuous change in economic activity at the time of the invasion.

4.1 Main Results

Table 1 presents estimation results at the city, federal-subject, and federal-district levels, indicating a statistically significant decline in overall NTL luminosity following the invasion. At the city level, the estimated coefficient suggests that the growth of NTL luminosity declined by approximately 4 percentage points post-invasion. Although a slight recovery appears in early 2024, it is temporary and is followed by a renewed decline (see Figure A1). The decline in NTL suggests a slow-down in economic activity, likely due to reduced business operations and supply chain disruptions. These results remain robust across various alternative specifications, including different NTL measures (sum and standard deviation) reported in Table B2 and specifications incorporating lagged NTL variables in Table B1.

[6] Russia is a federation of 83 regions with varying degree of autonomy: Republics, Krais (territories), Oblasts (regions), Federal cities, Autonomous oblasts (autonomous regions), and Autonomous okrugs (autonomous areas with a substantial ethnic minority). We do not include in our analysis the illegally occupied Crimea and Sevastopol, which Russia has been claiming as its 84th and 85th subjects since 2014, or the four regions of Ukraine that it attempted to annex in 2022. Legally, the Republics have more autonomy than the other regions, while the autonomous oblasts and okrugs are regions with significant ethnic minorities. The federal subjects are further grouped into eight federal districts, which serve mainly for the purposes of reporting and monitoring and which do not have their own separate governments or powers.

[7] Because this date falls near the end of February and we conduct our analysis using monthly data, we use March 2022 as the cutoff date.

Table 1: Impact of the 2022 Invasion on Nighttime Lights

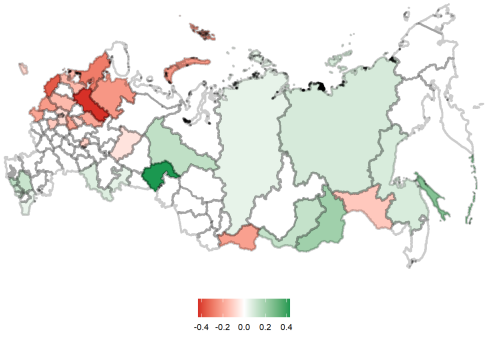
	(1) ΔNTL^{mean}_{city}	(2) $\Delta NTL^{mean}_{fed\_sub}$	(3) $\Delta NTL^{mean}_{district}$
invasion	-0.0416**	-0.0325*	-0.0160
	(0.0131)	(0.0154)	(0.0322)
N	96,543	8,037	776
Adjusted R^2	0.018	0.028	0.050
Trend	✓	✓	✓
FE: month	✓	✓	✓
FE: city	✓		
FE: federal subject		✓	
FE: district			✓
Cluster	Federal subject	Federal subject	District

Notes: Clustered standard errors are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. Dependent variable is the growth of the mean of nighttime lights in a city (column (1)) and the average growth of the mean of nighttime lights of cities in a federal subject (column (2)) or district (column (3)). *Invasion* equals one for months after March 2022. *Trend* is a linear time trend (months since February 2022).

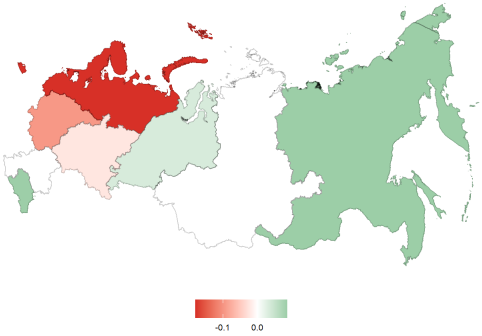
Next, we proceed with a descriptive overview of spatial heterogeneity to motivate potential mechanisms, followed by a formal empirical analysis in Section 5. Figure 1 illustrates the spatial variation in the estimated effects presented in Table 1. At the city level, economic impacts differ across regions: many cities in western and central Russia show declines in NTL, indicating a slowdown in traditionally industrialized and trade-oriented areas. These regions appear to be especially vulnerable to sanctions and disruption of trade links with Europe, which in turn may have constrained production and dampened business activity. In contrast, cities in the south and the Far East demonstrate relative resilience, with some even experiencing growth. This pattern reflects Russia's economic reorientation toward non-Western markets, state support for military industries, mobilization and casualty-related compensation payments, and increased infrastructure investment in its western regions. In Appendix A, we replicate the figures using alternative NTL measures, including the sum and standard deviation of lights, and find qualitatively similar results (Figure A3).

Figure 1: Spatial Impacts of Russia's Invasion of Ukraine on Average Night-time Lights in Russia

(a) Cities



(b) Federal subjects



(c) Federal districts

Note: Figure shows regression discontinuity in time results of the impact of Russian full-scale invasion on the year-on-year growth of the mean of nighttime lights on the level of individual cities (Figure 1a), federal subjects (Figure 1b) and federal districts (Figure 1c). City level results can be made available upon request. Federal subject level results are in Table B7, while Federal district level results are in Table B10.

5 Mechanism and Heterogeneity Analysis

The heterogeneity analysis suggests three complementary mechanisms shape the spatial economic effects of the invasion.[8] First, the economic impact of the invasion varies with proximity to international borders. As shown in Table 2, cities along the western and north-western borders experience larger economic slowdowns, particularly those bordering Belarus, Ukraine, Poland, Finland, and Estonia. This pattern is likely associated with disrupted trade links, sanctions exposure, and the withdrawal of foreign firms.

[8]For all analyses in this section, robustness checks using alternative outcome variables are reported in Appendix B (Table B2, Table B3 and Table B4).

Table 2: Baseline Results by Closest International Border

Panel A: Southern Borders					
	Caucasus		**Asia**		
	(1) AZE	(2) GEO	(3) KAZ	(4) MNG	(5) CHN
Invasion	0.0113	0.0913***	-0.0030	0.0121	0.0693*
	(0.0298)	(0.0251)	(0.0117)	(0.0216)	(0.0297)
Dependent variable	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}
N	578	5,665	33,724	6,065	6,227
Adjusted R^2	0.011	0.047	0.017	0.023	0.029
Trend	✓	✓	✓	✓	✓
FE: Month	✓	✓	✓	✓	✓
FE: City	✓	✓	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject	Federal subject	Federal subject

Panel B: Western Borders			
	(1) BLR	(2) UKR	(3) POL
Invasion	-0.1188***	-0.0342*	-0.1208*
	(0.0169)	(0.0193)	(0.0471)
Dependent variable	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}
N	19,283	12,707	1,313
Adjusted R^2	0.020	0.016	0.013
Trend	✓	✓	✓
FE: Month	✓	✓	✓
FE: City	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject

Panel C: North-Western Borders					
	Nordics		**Baltics**		
	(1) NOR	(2) FIN	(3) LTU	(4) LVA	(5) EST
Invasion	-0.0551	-0.2414***	0.0009	-0.6175	-0.1400***
	(0.0722)	(0.0342)	(0.2555)	(0.2487)	(0.0322)
Dependent variable	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}	ΔNTL^{mean}_{city}
N	1,216	5,858	563	248	3,096
Adjusted R^2	-0.003	0.027	0.008	0.024	0.030
Trend	✓	✓	✓	✓	✓
FE: Month	✓	✓	✓	✓	✓
FE: City	✓	✓	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject	Federal subject	Federal subject

Notes: Standard errors clustered at the city level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. See Figure A4 for the spatial distribution of cities by nearest borders. Countries are grouped by geographic orientation relative to Russia. Country abbreviations follow ISO-3 codes. Dependent variable is the year-on-year growth of the mean of nighttime lights in a city. *Invasion* equals one for months after March 2022. *Trend* is a linear time trend (months since February 2022).

Cities near the southern borders, particularly those bordering Georgia and China, show more moderate or even positive effects, suggesting a partial reorientation of economic activity toward non-Western markets. The relatively high mobilization rates in Southern and Southeastern Russia, and the associated payments, may also play a role. Overall, these results underscore how asymmetric border exposure and the loss of access to Western markets have generated uneven spatial economic outcomes following the invasion.

Second, the economic impact of the invasion varies with city size. Panel A of Table 3 shows that NTL decline most sharply in the smallest cities and remain significantly lower also in the largest urban centers, whereas mid-sized cities exhibit no statistically significant effects. This suggests different vulnerabilities along the urban hierarchy. Smaller cities (Column 1) are more exposed due to limited economic diversification, thinner labor markets and possible greater reliance of a few major local employers. Larger cities (Column 4), on the other hand, are disproportionately affected due to their greater integration into international markets, larger presence of foreign firms, and more service-oriented economic structures. Mid-sized cities, in contrast, appear relatively sheltered, potentially benefiting from a more balanced sectoral composition and lower exposure to international shocks.

Third, economic impacts differ across administrative structures (Table 3, Panel B).[9] Federal cities and oblasts experience the largest negative effects, likely due to their greater exposure to sanctions and to the withdrawal of foreign firms (Columns 2 and 4). In contrast, republics, autonomous regions, and krais, many of which contributed a large share of military personnel, do not show statistically significant declines in measured economic activity (Columns 1, 3, and 5). Indeed, Bessudnov (2023) finds that ethnic minorities (most notably Buryats and Tuvans) were substantially overrepresented among the enlisted soldiers and casualties incurred by the Russian Federation during the war. The insignificant finding for these regions probably reflects the contradictory impacts that an individual's enlisting, and his injury or death have for his home region. On the one hand, a soldier departing for the front removes one economically active person from the local labor force. In case of an injury or death, this effect may be permanent.

[9]The Russian Federation exhibits a hierarchical and asymmetric structure of regional autonomy: republics enjoy the highest degree of constitutionally entrenched self-rule, including their own constitutions and state languages (Arts. 66(1) and 68), whereas krais, oblasts, autonomous oblasts, and autonomous okrugs possess only general administrative autonomy within a uniform federal framework. The status of autonomous okrugs is further qualified by their possible inclusion within other federal subjects (Art. 66(4)); see also Arts. 5 and 71–73 of the Constitution of the Russian Federation (Russian Federation, 1993). See Figure A5 for the administrative map. Autonomous oblasts and autonomous okrugs are pooled because, unlike republics, they lack constitutionally entrenched sovereignty and exercise only administratively delegated autonomy.

Table 3: Heterogeneous Effects of the Invasion

Panel A: City Population Quartiles				
	(1) Q1 (Smallest)	(2) Q2	(3) Q3	(4) Q4 (Largest)
Invasion	-0.0774**	-0.0278	-0.0237	-0.0403**
	(0.0281)	(0.0202)	(0.0163)	(0.0132)
Range	994-14,420	14,420-29,136	29,136-61,746	61,746-11,514,330
Dependent variable	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}
N	23,954	23,953	23,953	23,953
Adjusted R^2	0.013	0.016	0.018	0.016
Trend	✓	✓	✓	✓
FE: Month	✓	✓	✓	✓
FE: City	✓	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject	Federal subject

Panel B: Type of Federal Subject					
	(1) Autonomous	(2) Federal City	(3) Krai	(4) Oblast	(5) Republic
Invasion	0.0399	-0.1652*	0.0305	-0.0627***	-0.0108
	(0.0832)	(0.0180)	(0.0278)	(0.0161)	(0.0274)
Dependent variable	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}	ΔNTL_{city}^{mean}
N	2,257	1,120	12,294	66,231	14,641
Adjusted R^2	0.029	0.032	0.023	0.017	0.023
Trend	✓	✓	✓	✓	✓
FE: Month	✓	✓	✓	✓	✓
FE: City	✓	✓	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject	Federal subject	Federal subject

Notes: Standard errors clustered at the federal-subject level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. The dependent variable is the year-on-year growth in average nighttime lights of a city. Panel A reports heterogeneity by city population quartiles in 2011. Panel B reports heterogeneity by administrative structure. Administrative structure is based on Article 65 of the Russian Constitution (Russian Federation, 1993), with the Jewish Autonomous Oblast and autonomous okrugs pooled together. See Figure A5 for the classification. All specifications include city fixed effects, month fixed effects, and a linear time trend.

However, the soldiers and their families benefit in the short run because of massive payments received upon signing up, as salaries, and as compensation for injury or death (Solanko, 2024). The Russian regions dominated by ethnic minorities tend to be disproportionately poor. The sign-up and compensation payments can therefore represent a significant monetary infusion into the local economy, which can fully, or more than fully, compensate for the loss of the individual's productive contribution in the short to medium term.[10]

[10]The Institute for the Study of War (ISW) reports that the average sign-up bonuses reached 1.47 million rubles or over 19 thousand dollars during the spring of 2026. See Russian Offensive Campaign Assessment, April 13, 2026; `https://understandingwar.org/research/russia-ukraine/russian-offensive-campaign-assessment-april-13-2026/`, accessed June 2026.

These results also demonstrate how wartime redistribution – such as mobilization and casualty-related bonuses, federal transfers, and increased public spending – offset local economic losses. Overall, the results suggest substantial regional variation in resilience to the war-induced shock. Differences in traditional markets, urban structure, and administrative status appear to influence how local economies absorb and respond to the shock.

A potential concern might be that the regional effects that we measure might be caused by deliberate efforts by Russian authorities and residents in order to reduce night-time light emissions to lower the risk of being attacked by Ukrainian drones and missiles. Such measures (blackouts) were common in past wars, such as World War II. We believe that such considerations are far less important in the current conflict. First-person-view (FPV) drones and loitering munitions, which are guided by sight, typically only operate in close proximity to the front line, which is now largely within the Ukrainian territory. Unmanned aerial vehicles (UAVs) and missiles with targets deep inside Russia generally rely on GPS. Since GPS signals can be jammed or disrupted, their navigation is further complemented by Inertial Navigation Systems (estimating the UAV's position based on the direction and speed of flight) and terrain-based navigation (whereby an on-board computer recognizes terrain features and compares them with preloaded maps). If visual navigation is required, this can also rely on thermal imaging and/or tracking the target's electro-magnetic signals. The availability of light visible to the human eye is therefore of limited importance (Khalaf-Allah, 2025).

Furthermore, Ukrainian attacks inside Russia mainly targeted sites in the proximity of the border, such as in the Belgorod and Kursk regions, until 2025. Thereafter, their scope was expanded significantly. Our data end in January 2025 and therefore do not capture this later expansion.

5.1 Evidence from Official Statistics

We present limited results based on official statistics to illustrate how conclusions drawn from administrative data compare with those based on remotely sensed measures, and to highlight the limitations of official indicators in capturing local economic disruptions after the invasion. To complement our main analysis, we use municipal-level data from Rosstat's Socioeconomic Indicators of Municipalities in Russia, covering the period 2005–2025. These data are drawn from the Rosstat Database of Municipal Indicators (DBMII), pre-processed and harmonized by

Esli Byt Tochnym (2025) as part of the Municipal Statistics of Russia Since 2005 dataset.[11] We focus on five economic indicators: (i) building permits, (ii) investment in fixed capital, (iii) the number of profitable firms, (iv) employment, and (v) the financial revenue of profitable firms.

Table 4: Baseline Results Using Official Statistics

	Number of building permits (ln)	Investment in fixed capital (ln)	Number of profitable firms (ln)	Number of employees (ln)	Financial revenue of profitable firms (ln)
Invasion	0.198***	0.104***	0.007	-0.007	-0.081
	(0.013)	(0.021)	(0.021)	(0.042)	(0.068)
N	43,974	27,573	11,452	17,250	11,396
Municipalities	11,892	2,897	2,467	2,866	2,463
R^2	0.277	0.123	0.000	0.000	0.056
Trend	✓	✓	✓	✓	✓
FE: Quarter	✓	✓	✓	✓	✓
FE: Municipality	✓	✓	✓	✓	✓

Notes: Standard errors are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. All outcome variables are in logarithms. All specifications include municipality fixed effects, quarter fixed effects, and a linear time trend.

Table 4 reports baseline treatment effects estimated using officially reported indicators. The results show positive and statistically significant post-invasion effects on construction activity and investment in fixed capital, while the estimated effects on employment, firm profitability, and financial outcomes are small and statistically insignificant. Appendix A, Figure A2 provides a spatial visualization of the estimated coefficients for investment in fixed capital, highlighting many municipalities with positive post-invasion responses. The purpose of this exercise is not to validate official statistics but to demonstrate how reliance on administrative data can mask spatial economic disruptions identified using alternative measures. However, interpreting these findings requires caution. Since the invasion, the Russian government has increasingly restricted the publication of official statistics, leading to uneven regional coverage, missing observations, and inconsistencies across indicators, including duplicate entries. Moreover, the indicators that remain publicly available appear selectively chosen and present a relatively favorable picture of economic conditions. Nevertheless, the regional pattern remains similar to our results obtained with NTLs: we see predominance of declines in western Russia and improvements in the east and the south.

[11] The dataset is publicly available under a Creative Commons BY 4.0 license and can be accessed via `https://archive.ph/Pf1bT`.

6 Conclusions

This paper demonstrates that major geopolitical shocks can significantly reshape a country's internal economic landscape and intensify spatial inequalities. Using Russia's February 2022 full-scale invasion of Ukraine as a natural experiment, we leverage high-resolution NTL data as a proxy for local economic activity to document a significant slowdown of economic growth across Russian cities, regions, and districts. Importantly, these effects are heterogeneous: regions in western Russia, most exposed to disruptions in trade with the West, experience a greater contraction, while areas in the East and Southeast have proven relatively resilient. We also find systematic differences between the urban hierarchy and administrative structures, underscoring how the local economic composition and institutional context shape vulnerability to external shocks. This study thus sheds light on the spatial mechanisms of economic adjustment and offers a framework for future research on the geography of economic shocks by using alternative data in contexts where official statistics are limited or subject to manipulation.

Our results thus document that the image painted by the official Russian statistics may substantially understate the economic disruption caused by the war. Our estimates imply both a lasting slowdown since the beginning of the full-scale invasion and a substantial regional redistribution of economic activity. The core, most populous parts, of Russia are the losers: they used to benefit from their geographic proximity to Europe and the resulting trade, which is now largely restricted by sanctions. By contrast, southern and eastern Russia have benefited from the redirection of trade through the Caucasus region, Central Asia, and China.

The evidence that Russia's official statistics likely overstate the true state of the economy can have important broader political and international implications. It suggests that the war has been more costly for Russia than the picture painted by the Kremlin would indicate. Correspondingly, Russia's bargaining position in any future ceasefire or peace negotiations may be weaker, and its ability to continue waging the war effectively may be more limited, than is commonly assumed.

Finally, the regional distribution of the winners and losers resulting from the current war may also have important political implications in the future. When the war ends and peaceful relations with the West are restored, western Russia will be the main beneficiary. This is where the Russian economic and political elites live. In contrast, eastern and southeastern Russia will

lose their current war-induced economic gains. Notably, these regions bore a disproportionately large share of the casualties incurred during the war (Bessudnov, 2023). The boost to their local economies may therefore prove to be short-lived, whereas the human cost that these regions suffered during the war will be permanent. Therefore, once the war is over, we can expect an increase in discontent with the outcome in the regions that currently appear to be gaining. This could significantly undermine the stability of any future regime that comes to power in Russia after the war.

Our research leaves considerable scope for future work on the impact of the war on the Russian economy and society. In particular, the mechanisms at play should be explored: the regional distribution of gains and losses may reflect the presence of specific sectors supplying the war effort such as the military-industrial complex, sanctions-busting trade flows with third countries, or the disbursements of sign-up and compensation payments to those joining the military or suffering injuries or death. NTL could also be used to assess the changes in oil and gas extraction in Russia, or damage inflicted on such facilities by Ukrainian counter-attacks; revenues from such activities play a crucial role in financing the continuation of the war. Measuring changes in NTL intensity at a relatively fine level of disaggregation could document whether the war has led to a spatial reallocation of economic activity (whether legal, informal, or illicit) from major urban centers to rural areas. Last but not least, the regional redistribution of economic activity within Russia should also translate into measurable gains in adjacent areas of neighboring countries such as the Caucasus region, Central Asia, and China.

Data Availability: The Russian spatial data used in this study are available online as the *Russian Cities Spatial Dataset* (`https://github.com/martinhulenyi/russian_cities`) at GitHub repository. Further details and a replication package are available upon request.

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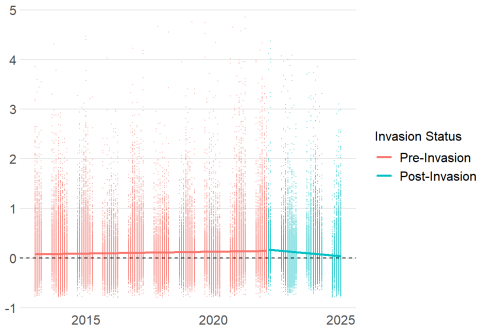
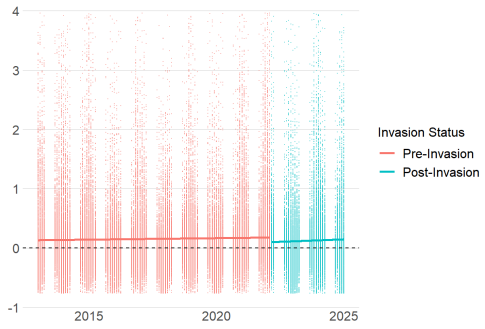
A Appendix: Supplementary Figures

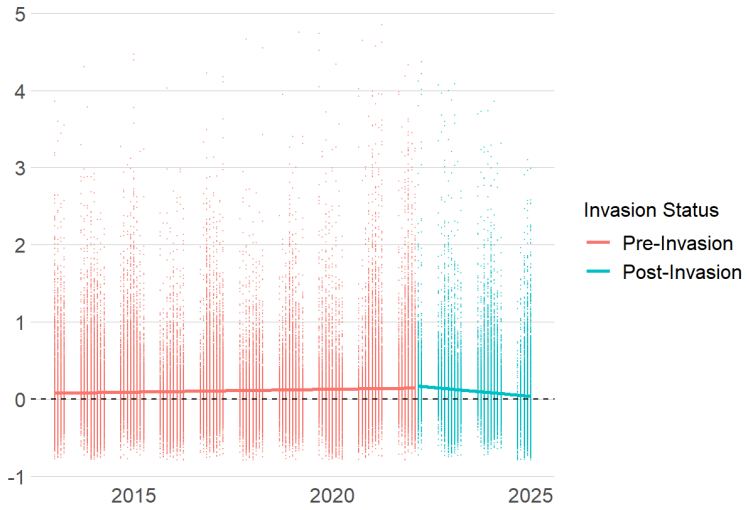
Figure A1: Dynamics of Changes in Nighttime Lights Pre- and Post-Invasion



(a) Sum of nighttime lights



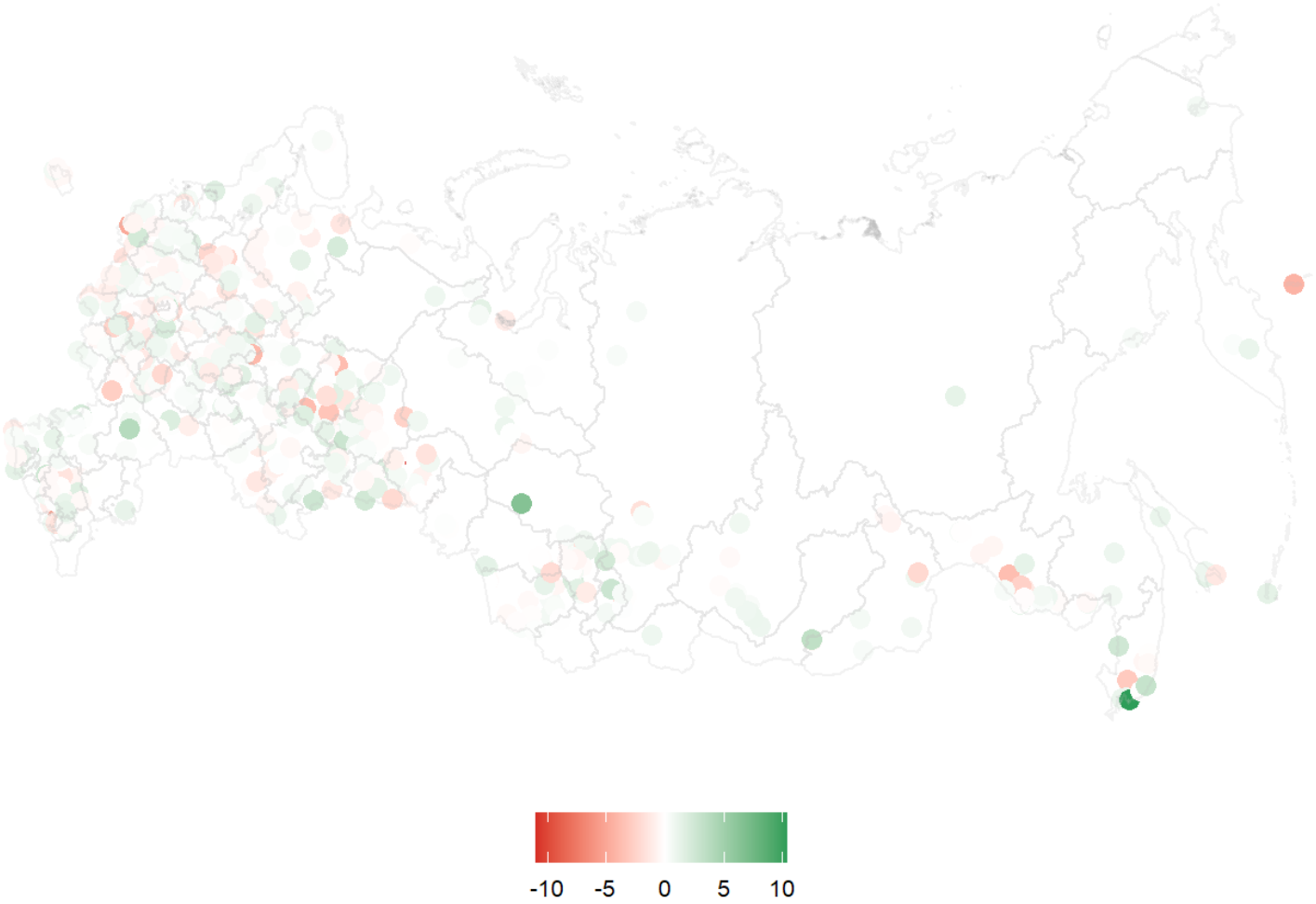
(b) Standard Deviation of nighttime lights



(c) Mean of nighttime lights

Note: Panel (a) shows the year-on-year growth of the sum of nighttime lights at the city level; panel (b) shows the year-on-year growth of the standard deviation of nighttime lights; panel (c) shows the year-on-year growth of the mean of nighttime lights.

Figure A2: Regression Coefficients by Municipality: Investment in Fixed Capital (Official Statistics)

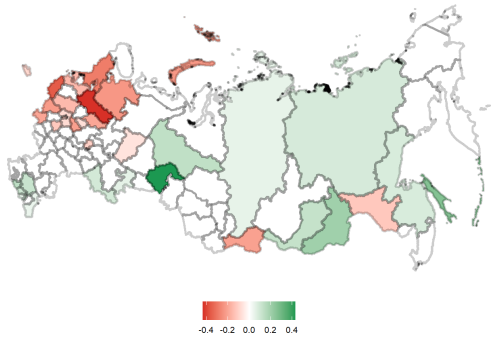


Note: Regression discontinuity in time results at the city level, with the dependent variable being the year-on-year growth of investment in fixed capital. Regression results can be made available upon request.

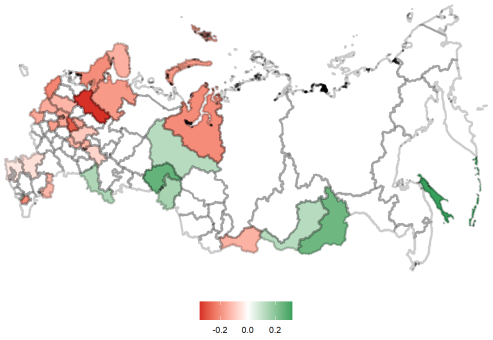
Figure A3: Impact of the Invasion on Nighttime Lights across Spatial and Administrative Levels.

(a) Cities: Sum of nighttime lights

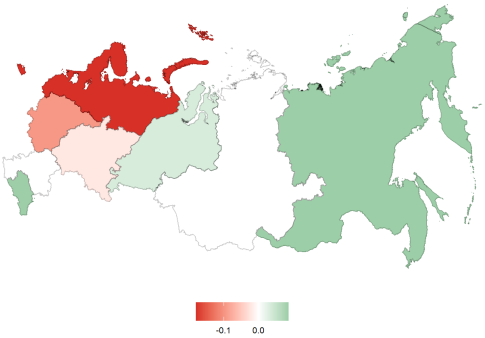
(b) Cities: Standard deviation in nighttime lights



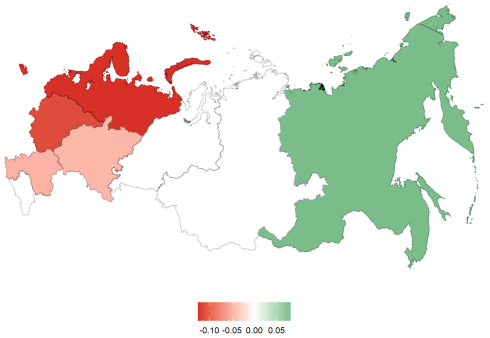
(c) Federal subjects: Sum of nighttime lights



(d) Federal subjects: Standard Deviation in nighttime lights



(e) Federal districts: Sum of nighttime lights



(f) Federal districts: Standard Deviation in nighttime lights

Note: Panels (a) and (b) show regression discontinuity in time results at the city level, with the dependent variable being the year-on-year growth in total nighttime lights (a) and in the standard deviation of nighttime lights (b); panels (c) and (d) show regression discontinuity in time results at the level of federal subjects, with the dependent variable being the year-on-year growth in total nighttime lights (c) and in the standard deviation of nighttime lights (d); panels (e) and (f) show regression discontinuity in time results at the level of federal districts, with the dependent variable being the year-on-year growth in total nighttime lights (e) and in the standard deviation of nighttime lights (f). City level results can be made available upon request. Federal subject level results are in Table B6 and Table B8, while Federal district level results are in Table B9 and Table B10.

Figure A4: Cities Categorized by Nearest Neighboring Countries (denoted by its ISO-3 Codes).

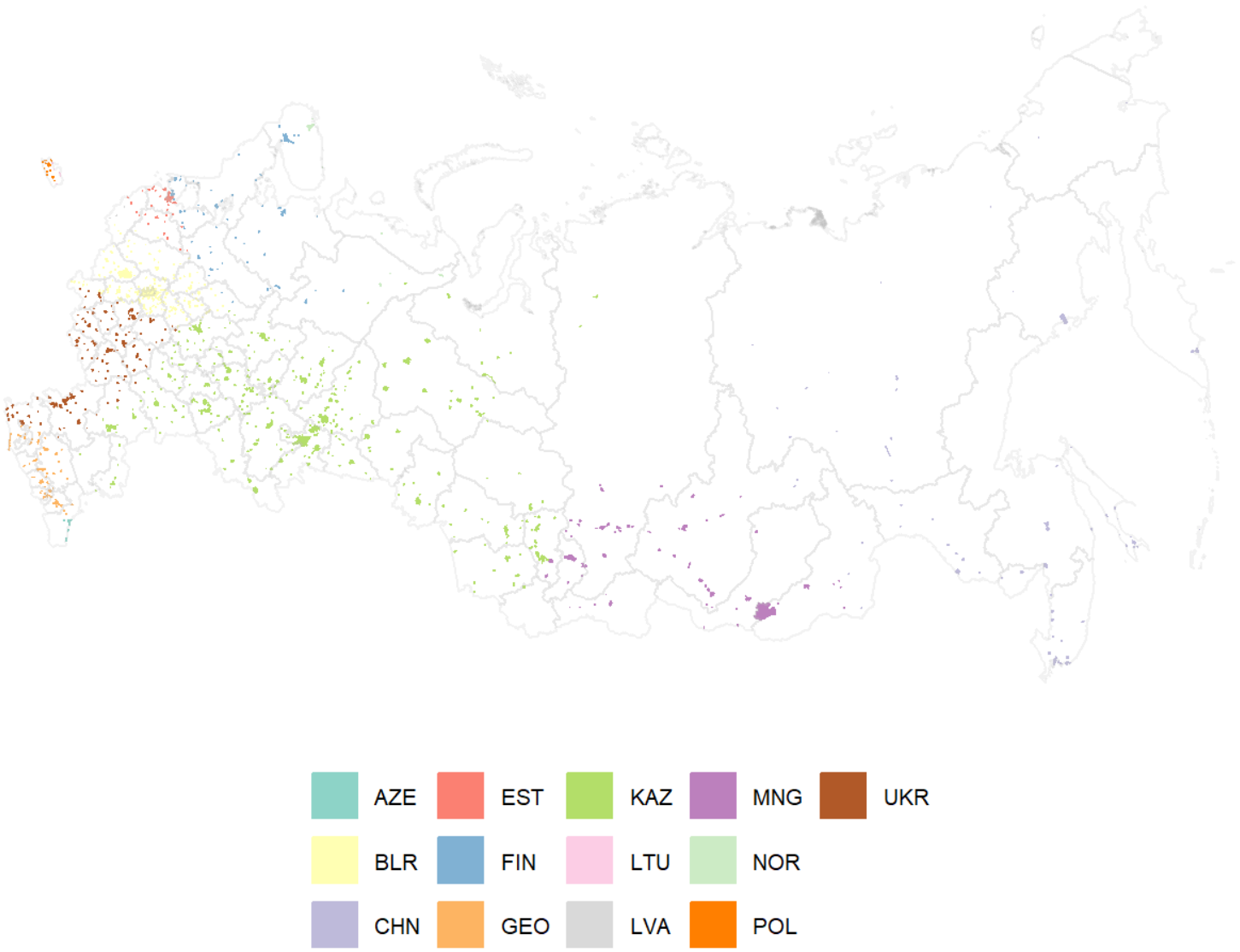
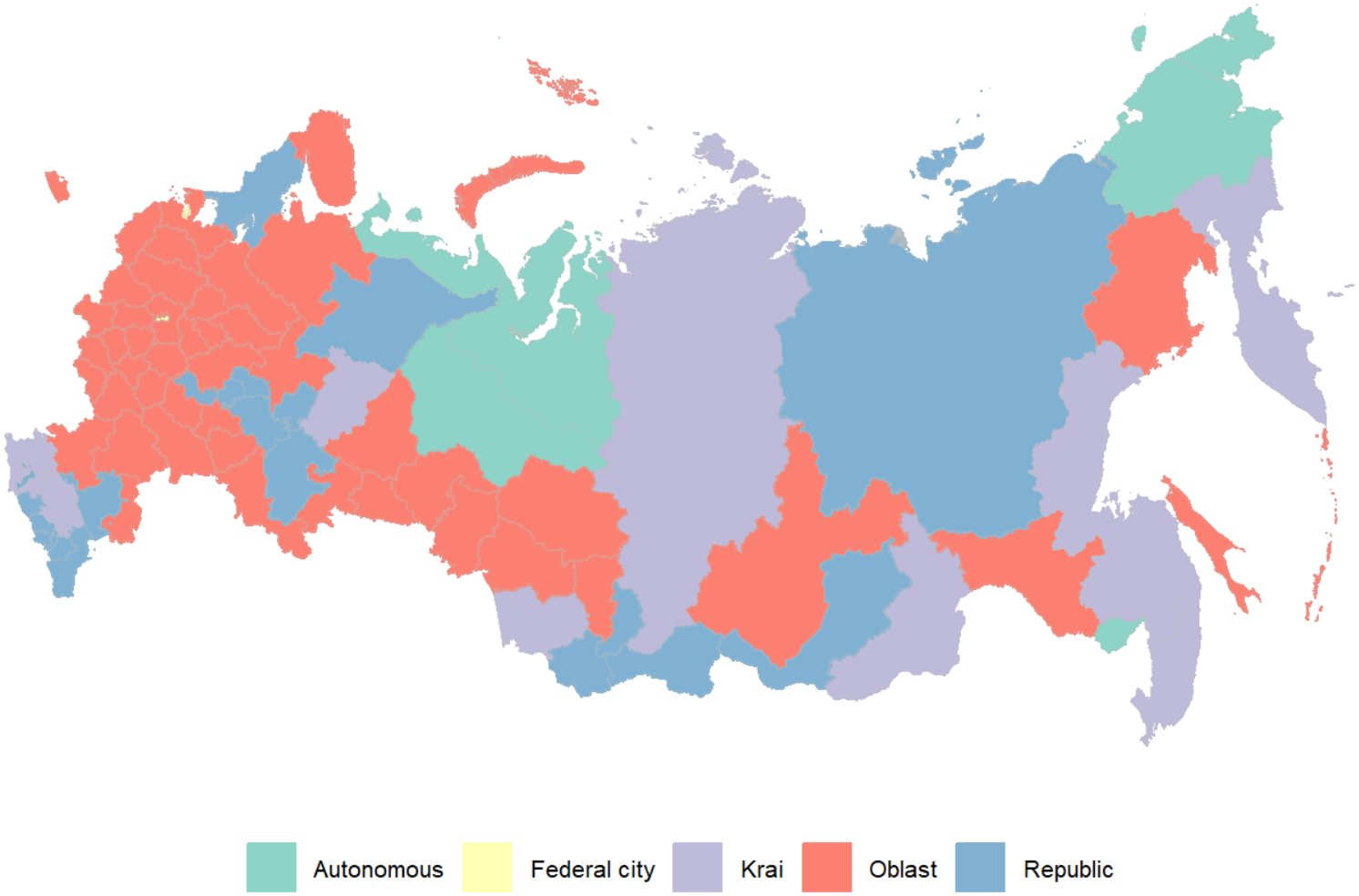


Figure A5: Federal Subjects Classified by the Degree of Autonomy.



B Appendix: Robustness Checks

Table B1: Impact of the 2022 Invasion on NTL

	(1) ΔNTL^{sum}_{city}	(2) $\Delta NTL^{stdev}_{city}$
Invasion	-0.0416**	-0.0547***
	(0.0132)	(0.0138)
N	96,543	96,543
Adjusted R^2	0.018	0.022
Trend	✓	✓
FE: month	✓	✓
FE: city	✓	✓
Cluster	Federal subject	Federal subject

Notes: Standard errors clustered at the federal level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. ΔNTL^{sum} and ΔNTL^{stdev} denote year-on-year growth of nighttime lights (sum and standard deviation). *Invasion* is an indicator equal to one for months after March 2022.

Table B2: Baseline Results with a Lagged Dependent Variable

	(1) ΔNTL^{sum}_{city}	(2) ΔNTL^{mean}_{city}	(3) $\Delta NTL^{stdev}_{city}$
$L1(\Delta NTL^{sum}_{city})$	0.4936***		
	(0.0197)		
$L1(\Delta NTL^{mean}_{city})$		0.4934***	
		(0.0196)	
$L1(\Delta NTL^{stdev}_{city})$			0.4259***
			(0.0222)
Invasion	-0.0256**	-0.0256**	-0.0413***
	(0.0084)	(0.0083)	(0.0102)
N	95,507	95,507	95,507
Adjusted R^2	0.257	0.257	0.200
FE: month	✓	✓	✓
FE: city	✓	✓	✓
Trend	✓	✓	✓
Cluster	Federal subject	Federal subject	Federal subject

Notes: Standard errors clustered at the federal-subject level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. ΔNTL^{sum} and ΔNTL^{stdev} denote year-on-year growth in total nighttime lights and variation in nighttime lights, respectively.

Table B3: Baseline Results by Closest Border

	(1) AZE	(2) BLR	(3) CHN	(4) EST	(5) FIN	(6) GEO	(7) KAZ	(8) LTU	(9) LVA	(10) MNG	(11) NOR	(12) POL	(13) UKR
Invasion	0.0113	-0.1194***	0.0693*	-0.1400***	-0.2416***	0.0914***	-0.0026	0.0009	-0.6175	0.0121	-0.0551	-0.1209*	-0.0342+
	(0.0298)	(0.0170)	(0.0297)	(0.0322)	(0.0343)	(0.0251)	(0.0117)	(0.2555)	(0.2487)	(0.0216)	(0.0722)	(0.0471)	(0.0194)
Dependent variable	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}
N	578	19283	6227	3096	5858	5665	33724	563	248	6065	1216	1313	12707
Adjsuted R^2	0.011	0.020	0.029	0.030	0.027	0.047	0.017	0.008	0.024	0.025	-0.003	0.013	0.016
Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FE: month	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FE: city	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	(1) AZE	(2) BLR	(3) CHN	(4) EST	(5) FIN	(6) GEO	(7) KAZ	(8) LTU	(9) LVA	(10) MNG	(11) NOR	(12) POL	(13) UKR
Invasion	-0.0392	-0.1455***	0.0668	-0.0420	-0.1800***	0.0348	-0.0260+	-0.0368	-0.4404	0.0127	-0.1038	-0.0663*	-0.0571*
	(0.0432)	(0.0196)	(0.0427)	(0.0328)	(0.0342)	(0.0305)	(0.0143)	(0.1715)	(0.2746)	(0.0281)	(0.0956)	(0.0293)	(0.0246)
Dependent variable	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$
N	578	19283	6227	3096	5858	5665	33724	563	248	6065	1216	1313	12707
Adjsuted R^2	0.028	0.029	0.029	0.027	0.021	0.024	0.019	0.008	0.016	0.029	0.001	0.011	0.023
Trend	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FE: month	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
FE: city	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: Standard errors clustered at the federal-subject level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$.

Table B4: Baseline Results by Quartile of Population

	(1) Quartile 1 (Least)	(2) Quartile 2	(3) Quartile 3	(4) Quartile 4 (Most)
Invasion	-0.0775**	-0.0270	-0.0237	-0.0411**
	(0.0281)	(0.0202)	(0.0163)	(0.0133)
Range	994-14,420	14,420-29,136	29,136-61,746	61,746-11,514,330
N	23,954	23,953	23,953	23,953
Dependent variable	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}
Adjusted R^2	0.014	0.016	0.018	0.016
Trend	✓	✓	✓	✓
FE: month	✓	✓	✓	✓
FE: city	✓	✓	✓	✓

	(1) Quartile 1 (Least)	(2) Quartile 2	(3) Quartile 3	(4) Quartile 4 (Most)
Invasion	-0.0578*	-0.0419*	-0.0485*	-0.0760***
	(0.0241)	(0.0201)	(0.0184)	(0.0194)
Range	994-14,420	14,420-29,136	29,136-61,746	61,746-11,514,330
Dependent variable	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$
N	23,954	23,953	23,953	23,953
Adjusted R^2	0.018	0.020	0.021	0.018
Trend	✓	✓	✓	✓
FE: month	✓	✓	✓	✓
FE: city	✓	✓	✓	✓

Notes: Standard errors clustered at the federal-subject level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. ΔNTL^{sum} and ΔNTL^{stdev} denote year-on-year growth in total nighttime lights and the standard deviation of nighttime lights, respectively. The columns correspond to city population quartiles in 2011, and the corresponding population size ranges (in number of persons) are reported in the row labeled *Range*.

Table B5: Baseline Results by Type of Federal Subject

	(1) Autonomous	(2) Federal City	(3) Krai	(4) Oblast	(5) Republic
Invasion	0.0399	-0.1653*	0.0305	-0.0627***	-0.0108
	(0.0832)	(0.0180)	(0.0278)	(0.0162)	(0.0274)
Dependent variable	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}	ΔNTL^{sum}_{city}
N	2,257	1,120	12,294	66,231	14,641
$Adhjusted\, R^2$	0.029	0.032	0.024	0.017	0.023
Trend	✓	✓	✓	✓	✓
FE: month	✓	✓	✓	✓	✓
FE: city	✓	✓	✓	✓	✓
	(1) Autonomous	(2) Federal City	(3) Krai	(4) Oblast	(5) Republic
Invasion	0.0135	-0.1248	0.0008	-0.0706***	-0.0350
	(0.0968)	(0.0249)	(0.0250)	(0.0175)	(0.0227)
Dependent variable	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$	$\Delta NTL^{stdev}_{city}$
$Adjusted\, R^2$	0.021	0.020	0.029	0.020	0.028
Trend	✓	✓	✓	✓	✓
FE: month	✓	✓	✓	✓	✓
FE: city	✓	✓	✓	✓	✓

Notes: Standard errors clustered at the federal-subject level are reported in parentheses. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$. ΔNTL^{sum} and ΔNTL^{stdev} denote year-on-year growth in total nighttime lights and the standard deviation of nighttime lights, respectively. Columns correspond to types of federal subjects.

Table B6: Effect of Invasion on the Year-on-Year Growth of the Sum of Nighttime Lights of Cities by Federal Subject

Oblast	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Altai Krai	0.027	(0.058)	1138	0.008
Altai Republic	-0.188	(0.115)	96	-0.063
Amur Oblast	-0.123	(0.084)	761	0.032
Arkhangelsk Oblast	-0.234*	(0.094)	908	0.016
Astrakhan Oblast	-0.077	(0.045)	569	0.014
Belgorod Oblast	-0.013	(0.062)	946	0.003
Bryansk Oblast	-0.203*	(0.080)	1307	0.008
Chechen Republic	-0.032	(0.092)	478	0.048
Chelyabinsk Oblast	0.055*	(0.023)	2442	0.011
Chukotka Aut. Okrug	-0.057	(0.158)	88	0.183
Chuvash Republic	-0.106+	(0.053)	841	0.011
Dagestan	0.042	(0.036)	850	0.002
Ingushetia	0.144**	(0.022)	459	0.052
Irkutsk Oblast	-0.022	(0.030)	2101	0.029
Ivanovo Oblast	-0.072	(0.054)	1533	0.019
Jewish Aut. Oblast	-0.050	(0.079)	190	-0.005
Kabardino-Balkar	0.103	(0.064)	638	0.027
Kaliningrad Oblast	-0.088	(0.088)	1692	0.015
Kalmykia	0.030	(0.167)	291	-0.016
Kaluga Oblast	-0.036	(0.042)	1799	0.005
Kamchatka Krai	-0.055	(0.078)	283	-0.003
Karachay-Cherkessia	0.140+	(0.058)	384	0.021
Karelia	-0.292**	(0.088)	1045	0.018
Kemerovo Oblast	-0.003	(0.040)	1762	0.016
Khabarovsk Krai	0.083	(0.063)	666	0.004
Khanty-Mansi	0.134+	(0.064)	1310	0.022
Kirov Oblast	0.042	(0.072)	1269	0.002
Komi Republic	0.053	(0.055)	830	0.009

Kostroma Oblast	-0.200+	(0.093)	1062	0.032
Krasnodar Krai	-0.017	(0.040)	2468	0.014
Krasnoyarsk Krai	0.051	(0.038)	1809	0.018
Kurgan Oblast	-0.010	(0.097)	868	0.043
Kursk Oblast	-0.038	(0.063)	843	-0.010
Leningrad Oblast	-0.157***	(0.034)	2713	0.037
Lipetsk Oblast	-0.039	(0.054)	731	0.037
Magadan Oblast	0.043	(0.153)	172	0.018
Mari El	-0.115*	(0.027)	277	0.004
Moscow	-0.139	(0.096)	284	0.017
Moscow Oblast	-0.081***	(0.018)	7020	0.031
Murmansk Oblast	-0.076	(0.053)	1474	-0.006
Nenets Aut. Okrug	0.266	(0.174)	95	0.023
Nizhny Novgorod	-0.038	(0.039)	2461	0.010
Novgorod Oblast	-0.111	(0.080)	912	0.021
Novosibirsk Oblast	-0.050	(0.075)	1239	-0.003
Omsk Oblast	0.040	(0.148)	566	0.012
Orenburg Oblast	0.093**	(0.023)	1043	0.026
Oryol Oblast	0.075	(0.054)	623	0.013
Penza Oblast	-0.051	(0.035)	738	-0.002
Perm Krai	-0.063	(0.049)	2245	0.009
Primorsky Krai	0.019	(0.041)	1156	0.002
Pskov Oblast	-0.362**	(0.108)	963	0.018
Republic of Adygea	0.060	(0.063)	190	-0.016
Rep. Bashkortostan	-0.028	(0.049)	1892	0.014
Republic of Buryatia	0.124+	(0.049)	570	0.038
Rep. Khakassia	-0.002	(0.031)	469	-0.002
Republic of Mordovia	0.010	(0.073)	572	-0.005
N. Ossetia-Alania	0.056	(0.028)	485	0.024
Rep. Tatarstan	-0.046	(0.027)	2097	0.029
Rostov Oblast	-0.003	(0.022)	2178	0.015

Ryazan Oblast	0.025	(0.107)	1119	0.030
Saint Petersburg	-0.178***	(0.035)	836	0.039
Sakha Republic	0.088	(0.096)	1224	0.039
Sakhalin Oblast	0.261***	(0.044)	1213	0.059
Samara Oblast	0.026	(0.049)	946	0.043
Saratov Oblast	-0.034	(0.044)	1526	-0.002
Smolensk Oblast	-0.225+	(0.116)	1399	0.023
Stavropol Krai	0.117	(0.069)	1610	0.060
Sverdlovsk Oblast	-0.019	(0.036)	4169	0.013
Tambov Oblast	-0.052	(0.117)	726	-0.007
Tomsk Oblast	-0.025	(0.155)	567	0.000
Tula Oblast	-0.122***	(0.024)	1769	0.007
Tuva Republic	-0.213**	(0.035)	384	0.015
Tver Oblast	-0.157*	(0.061)	1928	0.010
Tyumen Oblast	0.432	(0.258)	464	0.038
Udmurtia	0.082	(0.062)	569	-0.003
Ulyanovsk Oblast	-0.020	(0.021)	563	0.003
Vladimir Oblast	-0.216**	(0.059)	2043	0.039
Volgograd Oblast	0.035	(0.026)	1507	0.024
Vologda Oblast	-0.434***	(0.065)	1195	0.066
Voronezh Oblast	-0.063	(0.102)	1416	0.010
Yamalo-Nenets	-0.156	(0.133)	574	0.035
Yaroslavl Oblast	0.013	(0.036)	986	0.019
Zabaykalsky Krai	0.201*	(0.070)	919	0.035

Note: City and month fixed effects included. Cluster-robust standard errors at the city level.

Significance levels: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table B7: Effect of Invasion on the Year-on-Year Growth of the Mean of Nighttime Lights of Cities by Federal Subject

Oblast	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Altai Krai	0.027	(0.058)	1138	0.008
Altai Republic	-0.188	(0.115)	96	-0.063
Amur Oblast	-0.123	(0.084)	761	0.032
Arkhangelsk Oblast	-0.234*	(0.094)	908	0.016
Astrakhan Oblast	-0.077	(0.045)	569	0.014
Belgorod Oblast	-0.013	(0.062)	946	0.003
Bryansk Oblast	-0.203*	(0.080)	1307	0.008
Chechen Republic	-0.032	(0.092)	478	0.048
Chelyabinsk Oblast	0.055*	(0.023)	2442	0.011
Chukotka Aut. Okrug	-0.057	(0.158)	88	0.183
Chuvash Republic	-0.106+	(0.053)	841	0.011
Dagestan	0.042	(0.036)	850	0.002
Ingushetia	0.143**	(0.022)	459	0.052
Irkutsk Oblast	-0.022	(0.030)	2101	0.029
Ivanovo Oblast	-0.072	(0.054)	1533	0.019
Jewish Aut. Oblast	-0.050	(0.079)	190	-0.005
Kabardino-Balkar	0.103	(0.064)	638	0.027
Kaliningrad Oblast	-0.088	(0.088)	1692	0.015
Kalmykia	0.030	(0.167)	291	-0.016
Kaluga Oblast	-0.035	(0.041)	1799	0.005
Kamchatka Krai	-0.055	(0.078)	283	-0.003
Karachay-Cherkessia	0.140+	(0.058)	384	0.021
Karelia	-0.292**	(0.088)	1045	0.018
Kemerovo Oblast	-0.003	(0.040)	1762	0.016
Khabarovsk Krai	0.083	(0.063)	666	0.004
Khanty-Mansi	0.134+	(0.064)	1310	0.022
Kirov Oblast	0.042	(0.072)	1269	0.002
Komi Republic	0.053	(0.055)	830	0.009

Kostroma Oblast	-0.199+	(0.093)	1062	0.032
Krasnodar Krai	-0.017	(0.040)	2468	0.014
Krasnoyarsk Krai	0.051	(0.038)	1809	0.018
Kurgan Oblast	-0.010	(0.097)	868	0.043
Kursk Oblast	-0.038	(0.063)	843	-0.010
Leningrad Oblast	-0.157***	(0.034)	2713	0.037
Lipetsk Oblast	-0.039	(0.054)	731	0.037
Magadan Oblast	0.043	(0.153)	172	0.018
Mari El	-0.115*	(0.027)	277	0.004
Moscow	-0.139	(0.096)	284	0.017
Moscow Oblast	-0.081***	(0.018)	7020	0.031
Murmansk Oblast	-0.076	(0.053)	1474	-0.006
Nenets Aut. Okrug	0.266	(0.174)	95	0.023
Nizhny Novgorod	-0.038	(0.039)	2461	0.010
Novgorod Oblast	-0.111	(0.080)	912	0.021
Novosibirsk Oblast	-0.050	(0.075)	1239	-0.003
Omsk Oblast	0.040	(0.148)	566	0.012
Orenburg Oblast	0.072*	(0.027)	1043	0.024
Oryol Oblast	0.075	(0.054)	623	0.013
Penza Oblast	-0.051	(0.035)	738	-0.002
Perm Krai	-0.063	(0.049)	2245	0.009
Primorsky Krai	0.019	(0.041)	1156	0.002
Pskov Oblast	-0.362**	(0.108)	963	0.018
Republic of Adygea	0.060	(0.063)	190	-0.016
Rep. Bashkortostan	-0.028	(0.049)	1892	0.014
Republic of Buryatia	0.124+	(0.049)	570	0.038
Rep. Khakassia	-0.002	(0.031)	469	-0.002
Republic of Mordovia	0.010	(0.073)	572	-0.005
N. Ossetia-Alania	0.056	(0.028)	485	0.024
Rep. Tatarstan	-0.046	(0.027)	2097	0.029
Rostov Oblast	-0.003	(0.022)	2178	0.015

Ryazan Oblast	0.025	(0.107)	1119	0.030
Saint Petersburg	-0.178***	(0.035)	836	0.039
Sakha Republic	0.088	(0.096)	1224	0.039
Sakhalin Oblast	0.261***	(0.044)	1213	0.059
Samara Oblast	0.026	(0.049)	946	0.043
Saratov Oblast	-0.034	(0.044)	1526	-0.002
Smolensk Oblast	-0.225+	(0.116)	1399	0.023
Stavropol Krai	0.117	(0.069)	1610	0.060
Sverdlovsk Oblast	-0.017	(0.036)	4169	0.013
Tambov Oblast	-0.052	(0.117)	726	-0.007
Tomsk Oblast	-0.025	(0.155)	567	0.000
Tula Oblast	-0.122***	(0.024)	1769	0.007
Tuva Republic	-0.213**	(0.035)	384	0.015
Tver Oblast	-0.157*	(0.061)	1928	0.010
Tyumen Oblast	0.432	(0.258)	464	0.038
Udmurtia	0.082	(0.062)	569	-0.003
Ulyanovsk Oblast	-0.020	(0.021)	563	0.003
Vladimir Oblast	-0.211**	(0.058)	2043	0.038
Volgograd Oblast	0.035	(0.026)	1507	0.024
Vologda Oblast	-0.433***	(0.065)	1195	0.066
Voronezh Oblast	-0.064	(0.102)	1416	0.010
Yamalo-Nenets	-0.156	(0.133)	574	0.035
Yaroslavl Oblast	0.013	(0.036)	986	0.019
Zabaykalsky Krai	0.201*	(0.071)	919	0.031

Note: City and month fixed effects included. Cluster-robust standard errors at the city level.

Significance levels: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table B8: Effect of Invasion on the Year-on-Year Growth of the Standard Deviation of Nighttime Lights of Cities by Federal Subject

Oblast	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Altai Krai	-0.018	(0.078)	1138	0.012
Altai Republic	-0.107	(0.170)	96	-0.050
Amur Oblast	-0.084	(0.089)	761	0.027
Arkhangelsk	-0.183+	(0.086)	908	0.022
Astrakhan	-0.130*	(0.036)	569	0.015
Belgorod	0.028	(0.073)	946	0.024
Bryansk	-0.156+	(0.073)	1307	0.010
Chechen Rep.	-0.208	(0.169)	478	0.053
Chelyabinsk	0.025	(0.039)	2442	0.013
Chukotka	-0.101	(0.273)	88	0.058
Chuvash Rep.	-0.139+	(0.067)	841	0.012
Dagestan	-0.008	(0.050)	850	0.005
Ingushetia	0.110*	(0.028)	459	0.025
Irkutsk	-0.011	(0.037)	2101	0.021
Ivanovo	-0.152+	(0.082)	1533	0.023
Jewish Aut.	-0.112	(0.038)	190	0.004
Kabardino-Bal.	0.072	(0.129)	638	0.015
Kaliningrad	-0.049	(0.058)	1692	0.014
Kalmykia	-0.018	(0.203)	291	0.008
Kaluga	-0.023	(0.056)	1799	0.016
Kamchatka	-0.050	(0.081)	283	0.005
Karachay-Cher.	0.090	(0.073)	384	0.004
Karelia	-0.204*	(0.079)	1045	0.010
Kemerovo	-0.029	(0.053)	1762	0.016
Khabarovsk	0.033	(0.135)	666	0.012
Khanty-Mansi	0.124	(0.077)	1310	0.012
Kirov	-0.007	(0.089)	1269	0.010
Komi Republic	0.032	(0.078)	830	0.023

Kostroma	-0.084	(0.104)	1062	0.018
Krasnodar	-0.043	(0.046)	2468	0.019
Krasnoyarsk	0.018	(0.050)	1809	0.026
Kurgan	0.045	(0.112)	868	0.023
Kursk	-0.104	(0.085)	843	0.003
Leningrad	-0.055	(0.048)	2713	0.023
Lipetsk	-0.064	(0.084)	731	0.053
Magadan	-0.111	(0.114)	172	0.068
Mari El	-0.135	(0.051)	277	0.010
Moscow	-0.186	(0.134)	284	0.029
Moscow Oblast	-0.155***	(0.026)	7020	0.040
Murmansk	-0.144*	(0.066)	1474	-0.002
Nenets	0.279	(0.231)	95	0.014
Nizhny Novgorod	-0.099+	(0.051)	2461	0.017
Novgorod	-0.078	(0.053)	912	0.017
Novosibirsk	-0.069	(0.109)	1239	0.014
Omsk	0.148	(0.137)	566	0.017
Orenburg	0.138+	(0.070)	1043	0.033
Oryol	-0.010	(0.093)	623	0.017
Penza	0.003	(0.063)	738	0.012
Perm	-0.061	(0.071)	2245	0.018
Primorsky	-0.013	(0.049)	1156	0.008
Pskov	-0.223*	(0.090)	963	0.015
Adygea	0.079	(0.139)	190	-0.010
Bashkortostan	0.006	(0.047)	1892	0.017
Buryatia	0.125+	(0.053)	570	0.037
Khakassia	0.053	(0.074)	469	0.000
Mordovia	-0.134	(0.126)	572	0.016
N. Ossetia	0.077	(0.055)	485	-0.001
Tatarstan	-0.077	(0.047)	2097	0.032
Rostov	-0.057	(0.039)	2178	0.033

Ryazan	0.078	(0.140)	1119	0.033
St. Petersburg	-0.110+	(0.056)	836	0.025
Sakha	0.033	(0.145)	1224	0.038
Sakhalin	0.323***	(0.074)	1213	0.049
Samara	-0.044	(0.055)	946	0.021
Saratov	-0.032	(0.052)	1526	0.006
Smolensk	-0.152	(0.114)	1399	0.037
Stavropol	0.013	(0.062)	1610	0.022
Sverdlovsk	-0.048	(0.043)	4169	0.010
Tambov	-0.041	(0.179)	726	-0.003
Tomsk	-0.012	(0.167)	567	0.007
Tula	-0.175**	(0.049)	1769	0.020
Tuva	-0.140	(0.065)	384	0.014
Tver	-0.134*	(0.057)	1928	0.013
Tyumen	0.261	(0.193)	464	0.006
Udmurtia	-0.141	(0.142)	569	0.005
Ulyanovsk	-0.032	(0.065)	563	0.032
Vladimir	-0.289***	(0.053)	2043	0.042
Volgograd	-0.043	(0.047)	1507	0.030
Vologda	-0.350**	(0.090)	1195	0.048
Voronezh	-0.069	(0.097)	1416	0.019
Yamalo-Nenets	-0.208	(0.133)	574	0.048
Yaroslavl	0.106	(0.093)	986	0.029
Zabaykalsky	0.246+	(0.120)	919	0.060

Note: City and month fixed effects included. Cluster-robust standard errors at the city level.

Significance levels: + $p < 0.1$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table B9: Effect of Invasion on the Year-on-Year Growth of the Sum of Nighttime Lights of Cities by Federal District

Federal District	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Central	-0.096***	(0.015)	27534	0.017
Far Eastern	0.087**	(0.027)	7242	0.030
North Caucasian	0.086**	(0.024)	4904	0.048
Northwestern	-0.179***	(0.020)	12663	0.022
Siberian	-0.008	(0.020)	10131	0.015
Southern	-0.003	(0.018)	7203	0.018
Ural	0.035	(0.026)	9827	0.019
Volga	-0.024+	(0.014)	17039	0.016

Note: City and Month FE included. Cluster-robust standard errors by city.
*Significance levels: * p<0.05, ** p<0.01, *** p<0.001.*

Table B10: Effect of Invasion on the Year-on-Year Growth of the Mean of Nighttime Lights of Cities by Federal District

Federal District	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Central	-0.096***	(0.015)	27534	0.017
Far Eastern	0.087**	(0.027)	7242	0.030
North Caucasian	0.086**	(0.030)	4904	0.048
Northwestern	-0.179***	(0.024)	12663	0.022
Siberian	-0.008	(0.020)	10131	0.015
Southern	-0.003	(0.018)	7203	0.018
Ural	0.035	(0.026)	9827	0.019
Volga	-0.024+	(0.014)	17039	0.016

Note: City and Month FE included. Cluster-robust standard errors by city.
*Significance levels: + p<0.1, * p<0.05, ** p<0.01, *** p<0.001.*

Table B11: Effect of Invasion on the Year-on-Year Growth of the Standard Deviation of Nighttime Lights of Cities by Federal District

Federal District	**Invasion Coeff.**	**(Std. Err.)**	**Num.Obs.**	**Adj.** R^2
Central	-0.113***	(0.017)	27534	0.025
Far Eastern	0.082*	(0.038)	7242	0.034
North Caucasian	0.017	(0.033)	4904	0.025
Northwestern	-0.126***	(0.023)	12663	0.019
Siberian	-0.011	(0.025)	10131	0.021
Southern	-0.050*	(0.023)	7203	0.026
Ural	0.007	(0.028)	9827	0.014
Volga	-0.047*	(0.019)	17039	0.020

Note: City and Month FE included. Cluster-robust standard errors by city.
*Significance levels: * p<0.05, ** p<0.01, *** p<0.001.*

C Appendix: Summary Statistics

Table C1: Descriptive Statistics

Variable	N	Pre-invasion Mean [confidence interval]	Post-invasion Mean [confidence interval]
ΔNTL_{city}^{mean}	96,543	0.1115	0.1008
		[0.1083; 0.1148]	[0.0952; 0.1065]
ΔNTL_{city}^{sum}	96,543	0.1115	0.1010
		[0.1083; 0.1148]	[0.0954; 0.1066]
$\Delta NTL_{city}^{stdev}$	96,543	0.1567	0.1263
		[0.1524; 0.1611]	[0.1188; 0.1337]

Notes: The table reports average monthly year-on-year growth rates of nighttime lights at the city level, measured using the mean, sum, and standard deviation of nighttime light luminosity. Confidence intervals are shown in brackets. Pre-invasion refers to the period before the Russian full-scale invasion of Ukraine, while post-invasion refers to the period thereafter.