Economic Effects of the War in Donbas: Nightlights and the Ukrainian fight for freedom

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Abstract[1]

The conflict in Eastern Ukraine began in 2014, and it has now turned into a full-scale invasion. The separatist areas of Donetsk and Luhansk have remained isolated for the last eight years while fighting between rebels and the Ukrainian government has continued at a low but regular level since then. Previous studies analyze the impact of the war in Donbas on the economic situation in the region, such as the industry and GRP growth. However, this research uses data solely from the initial part of the conflict (2014-2016) and does not take into account the severity of the fighting. By using both the DMSP-OLS and VIIRS data as an approximation of economic activity in addition to the Uppsala Conflict Data Program (UCDP) casualty numbers, the analysis explores the effects of violent conflict on economic activity over a longer period of the Donbas war.

This paper uses both yearly and monthly satellite data in analyzing the general progression of the conflict in addition to the monthly progression. Furthermore, nightlight data of Ukrainian municipalities outside of Donbas are used in computing the Donbas region's nightlight data across several years. The UCDP data for civilian and battle-related casualties are used separately to show the causal effects of the different fighting severities. A Two-Stage Least Squares regression is used to see the effects of battle severity on economic outcomes.

JEL classification: F51; H56; O52; N44

Keywords: Donbas; Russo-Ukrainian; DMSP-OLS Satellite Nightlights; VIIRS Satellite Nightlights

[1] Please reach out to me at riadkanj@gmail.com if you have any comments or questions about the paper. After graduation, I will be working in management consulting.

1. Introduction

The current full-scale war in Ukraine might seem like the first time in many years that a violent conflict of this magnitude occurred in Europe. However, there was another war ongoing in Ukraine for the past eight years. Geopolitical problems began when in February of 2014 Russia annexed Crimea. Then what people call the "war in Donbas" began, an eight year conflict that was restricted to the Eastern part of Ukraine.[2] It was sparked by Russian-backed rebellious groups fighting against the Ukrainian government in hopes of achieving independence. The main reason for the conflict was the clash of political interests of the Ukrainian government and local leaders in the Donbas areas. Specifically, the Ukrainian government was hoping to be more aligned with the West, and the local areas were hoping to be more aligned with Russia.

According to the BBC, the conflict officially started in early April of 2014, when Donetsk became a self-proclaimed republic. The armed conflict further escalated when armed militants stormed police and government buildings in a nearby town of Sloviansk. On April 15th of the same year, the acting president of Ukraine, Oleksandr Turchynov, announced the start of an "anti-terrorist operation" against the rebels in the region. This could be considered the beginning of an armed conflict that went on until the recent full-scale invasion.

The Donbas region controlled by rebels is split into Donetsk People's Republic (DPR) and Luhansk People's Republic (LPR), with each republic having its own governments, economies, and the Russian Ruble as its currency, which differs from the currency used in Ukraine (Ukrainian Hryvnia). Prior to mid-February of 2022, the Eastern regions of Ukraine were not controlled by the Ukrainian government and were self-proclaimed republics. On February 21st of this year, the Russian president Vladimir Putin recognized the independence of those regions, saying that: "It has been long overdue". Previously, those republics were not recognized by any sovereign country. Throughout the war, economic activity was not recorded in territories occupied by the Ukrainian Government and in areas bordering the conflict zones. Furthermore, there is not much substantial research done on the effect that the intensity of fighting has on the economic activity in those towns.

This paper seeks to identify the relationship between estimated economic activity, measured through satellite nighttime imagery, and the intensity of fighting, measured through

[2] The terms War in Donbas, Civil War, and Armed Conflict are used in this paper to refer to the war in Eastern Ukraine that went on from April 2014 to February 2022.

battle-related deaths. Additionally, this paper studies property rights, and uses the distance to the border as a proxy of potential loss of houses to destruction. This study uses the example of the conflict in Ukraine, previously known as the Donbas war but now called the Russo-Ukrainian war. This study specifically uses economic data estimated on the district level of towns near the conflict zones and the intensity of fighting as proxied by the number of casualties in the war.

This paper adds to economic research available on civil wars that work to understand the effect that war and destruction possibilities in towns bordering the fighting can have on economic activity and development in those towns, potentially translating to applications in other geographical regions. Even though early in the Donbas war there was a lot of destruction in many of the bordering towns used in this study, as the conflict progressed, destruction levels converged throughout the towns based on their distance from the conflict's border, which is why this research can add to the analysis in stalemate conflicts.

This paper studies the war-affected regions from 2013 to 2019. I also include a much more focused study on the different parts of various cities using the high resolution available, and find that the part of town facing the conflict area has a slower economic development compared to the side of the town that is farther. The satellite resolution of up to 1 km, or 0.62 miles, is used for that purpose. This paper analyzes economic activity in detail by using many different data sets at the same time. This thesis uses two different datasets of EOG satellite nighttime images, spatial data, political control data, Ukrainian National Census Data, as well as many data sets that provide casualty numbers, and cease-fire violation records across many different time periods, to better understand what happens to economic activity during conflicts.

The results showed that ethnic composition of an administrative district plays a large role in its economic development. However, a district's distance from the front lines ended up showing conflicting results. This is likely due to the nature of the conflict, and it being influenced by foreign powers. As expected, due to more political isolation, the rebel-controlled areas ended up having lower levels of economic development. Unfortunately, in a quasi-proxy war like this, it is very difficult to understand the exact battle-related cause of the drop in economic activity. Therefore, further study, including the displaced persons data, would be required to understand the causality better.

1.1 Background

Ukraine has a landmass of 603,550 square kilometers (233,000 sq mi), making it the largest European country by size, and its population is 43.4 million, making it the 6th largest by population in Europe (excluding Russia and Turkey). Its location plays a significant role in a politico-economic relationship between Russia and Western Europe. An example of that can be seen with the construction of Nord Stream 2, that Russia built to avoid transporting gas through Ukrainian soil.

After achieving its independence in August of 1991, Ukraine lagged behind other Post-Soviet States in terms of its GDP growth. Ukraine has a similar demographic and economic industry composition (e.g. agriculture, chemicals, other exports) compared to some of the countries in the table shown below. This difference can be attributed to very high corruption (122/180 Corruption Perception Rank) as well as political and economic instability. Some of these events include:

1. the Orange Revolution in 2004, when the results of the 2nd round of the Presidential Election were annulled

2. the Euromaidan protests in 2013, by the end of which the Ukrainian President Victor Yanukovich was ousted

3. the annexation of the Crimean Peninsula by Russia in 2014

Using the World Bank estimates from 1996 to 2020 and taking the geometric average, we can see that Ukraine had the smallest GDP growth out of all European Post-Soviet States. Its GDP growth is even smaller than that of Russia, which has significantly slowed down in recent years due to the sanctions that have been imposed, and Russia's economic reliance on oil and gas exports. The conflict drove the Ukrainian GDP per capita to be the lowest in Europe, a title previously held by Moldova. Furthermore, it is difficult to measure the economic impact of the 2022 full scale invasion. Most of the agriculture, manufacturing, and coal production activities stopped, in addition to all the infrastructure destruction that is happening: one can only imagine what kind of impact this will have on Ukraine's economy for years to come. Even with the aid from abroad, Ukraine will not only need to rebuild the war destruction that happened, but will also need to figure out how its new economy will function.

Country	Average Annual GDP Growth (%)	GDP 2020 (Billions $)	Country	Average Annual GDP Growth (%)	GDP 2020 (Billions $)
Belarus	4.55	60.26	Moldova	2.64	11.91
Estonia	3.88	30.65	Russian Federation	2.73	1,483.50
Latvia	3.58	33.51	**Ukraine**	**1.11**	**155.58**
Lithuania	3.99	55.89	Average	3.21	1831.3

Table 1, GDP Growth from 1996-2020 (Source: World Bank GDP Data)

While it is clear that an armed conflict in addition to loss of sovereignty of many of its territories would play a large role in Ukraine's economic development, it is difficult to quantify that impact due to many conflicts happening simultaneously. An example of that is the loss of trade between the Crimean Peninsula and mainland Ukraine and the loss of vital industrial and coal producing regions in Eastern Ukraine that are now controlled by separatist forces, both of which happened around the same time period. Furthermore, not being able to fully understand this macroeconomic effect makes it difficult to see the impact that the armed conflict has on local regions in Ukraine. Thus, the following analysis is largely descriptive rather than precisely causal, since many disruptive events occurred simultaneously. However, when we contrast small regions, it is easier to explain differences in terms of intensity of local conflict.

Figure 1, Map of Ukraine and the Donbas Region highlighted (Source: ArcGIS)

The map above (figure 1) outlines Ukraine and includes the Donbas region, which is highlighted in blue. The intensity of fighting in Donbas has been constantly changing throughout the years. It has gone from intense in 2014 to less intense in the summer and fall of 2016 as well as during other cease-fire agreements, and now, back to intense fighting in 2022.[3] The intensity of fighting has unclear economic impacts on the towns surrounding the conflict zone. The investments in areas bordering the conflict area decrease with intensified fighting as investors worry about loss of capital in addition to migration patterns and changes in government investment. There are many towns that border the conflict zones, and it remains unclear how this conflict and its intensity impact them. Some larger towns, like the currently besieged Mariupol, had economic data recorded, including tax revenue, people employed, and minimum wages. However, this database only started in 2017. Fighting, which started in 2014, makes this database difficult to use if we want to see the impacts that the war had on its economic activity. Furthermore, some other towns like Volnovakha do not have economic data at all. Another problem is that this conflict is quite recent and the research to date on the economic activity during the conflict in Eastern Ukraine is general and is not limited to towns or smaller districts.

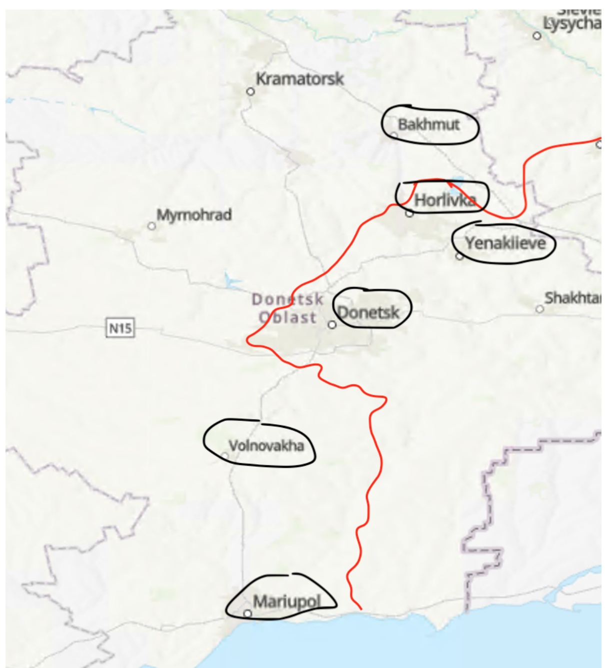

Figure 2, Conflict Map of Donetsk Oblast with Captured territory to the right of the red line (Source: ArcGIS)

[3] UCDP shows the number of deaths are markedly higher in 2014-2015, compared to the rest of the conflict

The above map (figure 2) includes the towns studied in this paper. These specific towns are circled. They are picked to provide relatively large metropolitan centers, but at the same time, also are chosen to provide different distances from the fighting areas and different bases of control, in this case either rebel-controlled or Ukrainian-controlled areas. As stated previously, many of those towns do not publish any reliable economic data.

Fortunately, there are many other ways to estimate economic activity, such as income and GDP. However, not all of them could be used in an area bordering a military conflict. Satellite nightlight data could be used to track economic activity in the areas bordering conflict. This paper uses the NASA Defense Meteorological Program-Operational Linescan System (DMSP-OLS) sensor, which has a digital archive from 1992 to 2019.[4] Additionally, this paper uses Visible and Infrared Imaging Suite (VIIRS) Day Night Band (DNB), a recent dataset that has better accuracy and higher resolution than DMSP-OLS. While using these data to track economic activity will create some limitations, which are noted in the data section, for the purpose of this research, it gives the possibility to track activity in areas where economic data were not recorded for prolonged periods of time. We also establish that these luminosity data are closely linked to GDP and population income at the aggregate level. More explanation on this is found in the literature review as well as the data overview.

2. Literature Review

2.1 Nightlights Data and Economic Activity

The satellite data images can be used to extract economic information. Donaldson and Storeygard (2016) highlight some historical examples of when measures akin to satellite images were used to get information on economic activity. The authors state the reasons for use of satellite images which align with this research. These reasons include the ability to obtain information that would be difficult to obtain otherwise and also have a wide geographic coverage. They argue that nightlights could be used as an approximation of economic activity if lighting is assumed to be a normal good, as this paper does. In addition, Donaldson and Storeygard provide

[4]https://ngdc.noaa.gov/eog/dmsp/downloadV4composites.html

other examples of how satellite data could be used, for example, when analyzing building types as well as climate and weather.

As a potential addition to nighttime data research, which will be the focus of this paper, future research could attempt to monitor economic activity through new construction projects in conflict areas. The paper concludes that as satellite data become more readily accessible as well as more accurate, there will be more research that will benefit from it and utilize it. This can be seen from the VIIRS data set that became available only recently. Furthermore, the paper highlights different interpretations in addition to limitations on the use of satellite images in economic research. The following image shows alternative use of satellite images for analyzing destruction brought by the current conflict in Ukraine.

Figure 3, Conflict Map of fighting in Mariupol Before and After. Late March 2022 (Source: CNN)

Henderson et al. (2012) focus on 188 countries from the early 1990s up to the early 2010s and observe their lights to draw similarities between the countries' reported economic data and satellite image estimates. They use images taken by the DMSP-OLS. These sensors measure light intensity and can be processed to analyze economic data. The authors in this case built a framework to approximate a population's income from satellite images. They assume that there is a simple constant elasticity relationship between total observable lights and income. Other assumptions include assuming that lights are growing the same way in the number of people and per capita income. These data are used as well to find a relationship between luminance and GDP with controls for luminance technology in different parts of the world and daytime activities that are not measured by nighttime data.

From their findings it can be seen that there is a lights to GDP elasticity from 0.28 to 0.32, which is a substantial value. They used official GDP numbers in addition to satellite images to improve the accuracy of official income estimates. As we use the same data sets as Henderson et al. (2012), therefore, the luminosity ranking of each pixel ranked from 0 to 63, with 0 being completely dark and 63 being representative of a well lit area, is relevant to this paper as well. Furthermore, their findings showed that it was indeed useful to look at this data as a proxy of economic activity, especially when no other data are available. Even though these papers do not focus on studying conflict zones or areas surrounding them, this research could be used as a baseline to show that there is the opportunity to estimate the economic activity in areas where other data are not available, such as those smaller Eastern Ukrainian towns.

2.2 War regions and NightLights

There has been some research made on conflict and nighttime data, but there has not been research exclusively focused on conflict intensity and economic activity measured with nighttime data. One of the research papers that studies the use of nighttime data is a paper by Bundervoet, Maiyo, and Sanghi (2015), where the authors measure national and subnational economic growth. Their focus is on estimating the subnational GDP of Sub-Saharan Africa using the nighttime data. Many of these countries have gone through national shocks that affected their economic activity. A helpful section from this paper is the study that the authors used on the Eritrean-Ethiopian border conflict of 1998-2000. The nature of the conflict is similar to that of Donbas, since it also has ethno-demographic causes. The two conflicts could be compared by associating the Russian-backed rebels to Ethiopia and Ukraine’s government to Eritrea, in terms of relative country and economy sizes. The main takeaway was that, as expected, there was a correlation between nightlights and lower economic activity due to conflict. They also find that the dip in nightlights occured before the dip in GDP, and both picked up after the conflict was over and economic activity resumed. The lag likely happened because of the potential time it takes in updating national accounts, since nighttime data reflects immediate changes. Moreover, GDP takes many more factors into consideration, thereby taking more time to reflect the change in consumer behavior, migration, and/or change of production. Otherwise, the paper adds to the consensus that lights serve as a good economic estimation for both conflict and non-conflict times. These conclusions would be used to estimate economic activity in Donbas on a subnational level as well as see what effect the intensity of conflict has on it.

2.3 Economics of War Regions

It is important to look at studies that analyze what kind of impact a conflict has on different regions. A study by Abadie and Gardeazabal (2003) focuses on what happened in the Basque Country in Spain, which was one of the richest regions in the whole country. The study of Basque Country is helpful for drawing a comparison between the Eastern Ukrainian region, as both regions had much potential for economic growth. In addition to that, many investors and corporations in Eastern Ukraine were targeted and seized by the de-facto government at the beginning of the conflict, which is similar to what happened in Spain with entrepreneurs and corporations both being targets of violence.

The authors focus on the effect of military conflict on economic instability, and they tried to rule out the errors that could be caused by created conflict in already unstable economic states. This set is helpful as even though overall the Ukrainian population experienced some instability due to currency devaluation, the particular region of Donbass had steady GDP growth (Sushchiy and Medvedkin 2018). The authors constructed a synthetic state, an artificially constructed state that would serve as an approximation of what Basque's economic activity would look like if there were no terrorism in the region. After building out the study, they estimated that the effect of terrorism on the GDP gap is negative for every time lag. This shows that the decrease in investment could be explained by the violence happening in the region. The authors stated that terrorist activities lead to migration and deter investors from putting their capital there.

The Donbas region was completely locked out from Ukraine, and sanctions made investments from foreign investors impossible. Therefore, the exact analysis that the authors used for terrorist activities is not applicable to analyzing the situation in Donbas, though there are some parallels. Furthermore, while Abadie and Gardeazabal (2003) do not use nighttime lights data, it is helpful in establishing the base of what effect violence or conflict can have on economic activity. It is difficult to classify the war in Donbas as either a war for independence, with terrorist acts done by local rebels, or as a foreign intervention, but it is clearly an armed conflict that has negative impacts on the capabilities of this region to trade and grow economically. Donetsk

Oblast, which once was the second highest region by GDP pre-war, would be only an average Ukrainian oblast in terms of GDP (prior to 2022) using current estimations.[5]

2.4 Eastern-Europe

The conflict in the Donbas region has had strong impacts beyond its borders. The paper by Dreger et al. (2016) analyzes one type of impact that the conflict had, namely the impact on its neighboring economies. This paper looks at what effect sanctions had on the Russian economy. It analyzes whether the fall in Russian GDP per capita was due to sanctions or due to the fall in oil prices. The authors conclude that the fall in oil prices was more significant in affecting the drop in Russian GDP. While this is not the outcome that the authors had anticipated, it remains relevant for the analysis of this paper. It takes a specific approach in analyzing all the sanctions imposed in addition to a look at oil prices. It thus serves as a valuable resource in understanding the Russian economy. As previously stated, a positive outlook for the Russian economy could mean that Russia is able to better support the Donbas regions, so improvement in economic conditions would not necessarily be coming from reduced intensity of fighting.

2.5 Donbas Background

There is already research done on the situation in Eastern Ukraine. Sushchiy and Medvedkin (2018) focus on analyzing the political, ethno-demographic, and socio-economic situation in the areas of conflict and the self-proclaimed republics of Eastern Ukraine. The paper highlights a lot of political and ethno-demographic changes that happened and will potentially happen due to the armed conflict, with one example being the change in population of ethnic Russians in those regions and population changes in general. While the empirical part of the paper is short, some parts of its economic analysis section is used for this research. The paper contains a thorough analysis of the economies of Donetsk and Lugansk, the areas currently in conflict. These regions are heavily metallurgical, with many machine-building enterprises and coke production plants. Beyond this, the economies have large populations with a previously strong finance center in Donetsk in addition to a chemical production sector.

Furthemore, the paper has a quantitative analysis on the index of industrial production, which could be used as another proxy to economic activity in this paper. This index follows a

[5] Державна служба статистики України (the Ukrainian National Statistics Agency)

similar trend to satellite nighttime data trend that is presented later in the paper. The paper also emphasizes that the Ukrainian state statistical services correct the data retroactively, which affects their validity. The paper includes much helpful data such as estimates of population movements, maps of industrial areas, and economic activity analysis. It is useful in identifying which border towns, either under Ukrainian control or under the control of separatist forces, are important to analyze. Currently, with this and other analyses, I will be looking at towns such as rebel-controlled Donetsk, Yenakiive, and Horlivka, and Ukrainian-controlled Mariupol, Bakhmut, and Volnovakha, all circled in Figure 2. Looking at towns controlled by both sides of the conflict could provide a more representative image of how the intensity of the conflict is affecting economic activity. The nighttime data adds onto the data sets being used in the paper and serves as another tool of estimation of economic activity where it is not available otherwise.

Adding to this research is Zhukov (2015). Zhukov's paper analyzes micro-level data available on the conflict, similar to the approach I take. However, the author uses it to analyze the impact of the reasons for which the conflict started in the first place. Zhukov concludes that areas that were economically dependent on Russia or had a certain employment mix, high percentage of miners compared to other professions, were more likely to be rebellious. The paper uses extensive data from local municipalities including pre-war employment rates, ethno-linguistic populations, voting patterns in addition to average incomes, to make conclusions and decide on which factors pushed the war to start or pushed the population to rebell.

This research paper does not explore reasons for the start of the conflict, but rather studies the events during the conflict. The thesis analyzes only battle-related deaths, so what could be a shelling incident may not necessarily be related to battle-related deaths. Therefore, a completely different dataset from Zhukov's is used. Zhukov has already built a data set using a human assisted coding machine, which collected violent incidents in Donbas since February of 2014 by each news report (*N*=53,754). However, there are some issues with this data set as it also includes ethno-racial hate crimes, occupation/stormages of government buildings, and protests. These events are indeed economically destabilizing, but they are not useful for this research, as I will focus on war conflicts with casualties. Therefore, this paper uses battle-related deaths, civilian deaths, and OSCE recorded violations instead. This is because smaller incidents that are reported in the media might not be necessarily strong/scary enough to make people move from where they live.

Closer to my work, Bluszcz and Valente (2020) address the economic effect that the conflict had on the Donbas region. They analyze how strong the negative impact was present locally as a result of the conflict. The general case that the authors look at is the case of Hybrid Wars, which are common in today's political environments. Hybrid wars in their paper refer to the use of insurgent tactics and conventional military power to achieve politico-strategic goals, which in this case are goals of powerful countries like Russia. Similar to Abadie and Gardeazabal (2003), they create a synthetic state to compare the current economic situation to what the Donbas region would look like if there were no conflict.

Bluszcz and Valente (2020) begin to record the conflict period from 2013, since there were some violent protests at the end of that year that may have affected the country's GDP per capita. Since everything was still calm in Donbas in 2013, I will use 2013 as the control year. The regional analysis is especially interesting, since the paper focuses on Donetsk and Luhansk areas. Those findings also provide an example of what a more localized analysis through satellite looks like. In this case, Bluszcz and Valente (2020) find that GRP is initially decreasing and then increasing after 2015, which is similar to what is found in this thesis paper. This is potentially due to change in fighting patterns and in the intensity of fighting measured through battle casualties.

Although on aggregate level, the paper still provides a helpful analysis on the underlying mechanisms that led to the GDP decline. The authors state that disruption in production, trade and employment, as well as public expenditures, and military mobilization were a few of the strongest factors contributing to the lower GDP per capita. Some of these factors are difficult to analyze or control for, using the satellite images. One of the strongest effects were trade disruptions. The Donbas area was heavily reliant on the export of coal, but the destruction in infrastructure and the trade sanctions in addition to the non-reliable electricity supply led to many mines being flooded and unreliable. Their findings showed that the per capita GRP of the Donbas region is on average 47% ($3,825) lower than its synthetic counterparts which were not affected by the war. However, the authors report that there is not much empirical evidence on the costs incurred by Ukraine at the national level because of the war. This is shown by only a small dip in Ukraine's GDP PPP presented later in this paper. While the authors do fill some of the higher level gaps, my thesis looks much more into the details based on each city. Furthermore, the authors state that looking at the longer term migration dynamics and pursuing more studies with newer data would be helpful. This thesis should address both of these issues since the most recent data used by the authors is from 2016, and there are satellite data images available through 2019. Furthermore, nightlight data are a great indicator not only of economic activity but of population changes as well, which should address this issue that the authors were not able to address in their paper. It should be possible to disentangle these effects further by using internally displaced persons data together with satellite nighttime images, which were not possible to retrieve at this point due to the current invasion of Ukraine.

3. Theoretical Background

3.1 Accuracy of Nightlight data

It is important to analyze how accurate the nightlight data will be in predicting GDP or economic activity in Eastern Ukraine. Research on this has been done by Elvidge, Hsu, and Tilottama (2017), where the authors looked at the relationship between nightlight data and the GDP and population. The analysis focused on Eastern European and Post-Soviet countries. The authors classified the countries they had analyzed into three categories. The first category is for the countries where nightlight increase is associated with economic growth, and including Albania, Poland, Romania, and Croatia. The second category is for the countries where nightlight growth is slow despite strong economic growth in industrial sectors and despite higher government spending in addition to growth in consumption. Countries from this list include East Germany, Hungary, and the Czech Republic. The third category includes countries that had initial loss in nighttime lights followed by economic growth. The loss in nighttime lights could have been associated with many different things. In some cases it could have been associated with conflict, such as rebel-controlled South Ossetia. In other cases, the loss of nighttime lights could have been due to the country's dependence on its neighbor for electricity, which is the case with most of the countries in the third category. After the USSR dissolved, there were agreements between its republics on the trade of goods and services. The strongest trades included electricity production or fuel trades as well as skilled labor trades. Many countries in the third category were highly dependent on their neighbors to produce electricity. After the USSR fell apart, its electricity production capabilities fell. The trend, however, reversed during the 2000s.

The paper finds that for Ukraine, nightlights are strongly and positively correlated with population but not with the GDP. While it can be argued that nightlight data analysis would not be appropriate for Ukraine, it is important to take note of the different economic and political situations occurring in countries of the third category compared to those from other categories. Furthemore, the latter analysis was done through 2012, but the data used for this research paper start in 2014 and the trend reversion is even clearer. As Ukraine's economy and infrastructure was restored towards the end of 2010s, using data from 2014 would make this analysis appropriate. Additionally, the authors state that there was nightlight growth through 2012 and that this trend continues after, supporting the point that this paper's data set is appropriate for the GDP nightlight analysis. This allows the research starting in 2014 to be more accurate, especially since it is used on the level of municipalities rather than the whole country. The authors state that, after 2002, there was a strong urban lighting growth and rural light development in Ukraine. Since the Donbas region is highly urban, it is very probable that if a similar analysis were done on that region exclusively, it could show a high correlation between nightlights and GDP. Further, the drop in nightlights, which initially lowered the correlation between nighttime data and GDP, could be explained by the diminished electric power generation capacity for the post-Independence decade, hence showing the low correlation prior to 2012 between nighttime data and GDP in Ukraine. After Ukraine revamped its electric grid and restored electric generation capacity in the 2010s, the correlation between GDP and nightlight data should be strong, similar to countries in the first category. Furthermore, poor quality GDP data and low correlation between regional living standards and Ukraine's overall GDP allow us to use satellite data instead. Accounting for all these factors, it is clear that nighttime data could be used in Donbas with the purpose of estimating economic activity.

3.2 Ethnicity Variable usage

Conflict is also studied through nighttime data by Rohner, Thoenig, and Zilibotti (2013). They focus on ethnic conflicts in Rwanda between 2002 and 2005. The analysis mainly looks at spatial and ethnic causations of fighting and what effect they have on trust based on ethnic identity in the country. Their argument is that trust is important for good economic activity, which is not the focus of this research; of relevance here is that the authors use nightlight data to estimate regional economic activity at the county level. They conclude that in fractionalized counties, meaning counties with people from different ethnic groups, there was a correlation between fighting and nightlights. However, there was no correlation between fighting in non-fractionalized counties. This could be another variable that could have an external effect on the regression. Many counties and towns on the border of the conflict area have people from both ethnicities. Therefore, the results should also be significant in those areas if we analyze the effect of intensity of fighting on economic activity. In this case ethnicity is used, and a variable is created that captures the difference between areas with homogeneous ethnic distributions and areas with more heterogeneous ethnic distributions.

3.3 Casualties variable usage

O'Loughlin and Witmer (2011) provide another important study that helps analyze the intensity of conflict. The paper analyzes the armed conflict in North Caucasus of Russia from 1999 to 2007. There are a lot of similarities between the conflict that happened in the North Caucasus and what is currently happening in Eastern Ukraine, including but not limited to a significant Russian population, alleged and non-alleged intervention of Russian armed forces, ethnic cause of the conflict, and a chance for potential escalation lasting many years. The paper builds a database of 14,177 violent events that were recorded from media and other sources, and it pinpoints the locations of these events to analyze the most common locations for violence and look for geographical patterns. The authors generate space-time kernels for violent events, and using Monte Carlo simulations, they find strong space-time interactions with the data. They conclude that there is a correlation between violence in certain locations and higher presence of ethnic Russians, and that Russian populations were less likely to be bombed. This paper is helpful in establishing the collection method of violent events and the ability to use ethnicity as a variable.

Furthermore, the paper highlights the limitations of this data collection method. The main issue is the freedom of media outlets and potential danger to reporters within the separatist controlled regions. Similar to what happened with reporters covering the North Caucasus War, there were issues with reporters covering the war in Donbas.[6] The Russian reporters in Donbas, who were biased towards Russia, would be inclined to underreport their casualties but overreport Ukrainian casualties. A similar issue would be true in the case of the Ukrainian reporters who would be inclined to show their success at the war. It is important to understand the extent to which this is factual, which is explained more in the data section of this paper. Therefore, this research thesis is heavily reliant on the UCDP dataset, in addition to manual mapping, which in total should serve as a neutral source.

Additionally, the use of casualties as a measure of violence has been explained by Gates et al. (2012), who analyze the longer impacts that war can have on populations. They specifically analyze civil wars, which makes their study especially relevant. Their analysis of conflict severity through battle-related deaths is similar to the analysis this paper undertakes. The authors analyze the effects of armed conflicts while taking into account the United Nations Millennium Development Goals (MDG) and economic growth.[7] The authors specifically analyze the extent to which the gap between non-conflict areas and conflict areas is due to the conflict specifically or rather is due to some other factor that could be the underlying reason for the conflict in the first place. The authors use a data set that has observations only once every 5 years, which is not as frequent of an analysis as in this thesis. The authors, however, complete their analysis across many countries. They used Coarsened Exact Matching, which is a method that pairs countries together based on similar conflicts. They excluded highly industrialized countries, such as most Western European countries, the United States, as well as Australia and New Zealand. Overall, their research finds a causal relationship between conflict and the inability to attain the MDG goals. This paper just serves as another example where the intensity of conflict is measured by battle-related deaths and where a causal relationship is found between more severe conflicts and lower MDG goals in addition to lower economic growth. This study will use a much more frequent data collection method and apply it in a specific geographic location as opposed to many.

Further, another interesting research paper was done by Dodd (2021) on the Civil War in Bosnia using satellite nightlight data. The paper serves as a good background in showing how the economy of a country is affected by a conflict. This paper, presented and studied through satellite

[6] Kidnapping of an American journalist in Donetsk. Source: https://www.wgbh.org/news/post/american-journalist-kidnapped-ukraines-pro-russia-insurgents

[7] Set of goals that the UN established includes eradicating poverty and hunger, increasing education. More on this: https://www.un.org/millenniumgoals/

nighttime data, is used as reference in the writing of this thesis. Some of the findings with regards to the use of satellite data are applied in this paper.

4. Data Overview

4.1 Satellite NightLight Data

This paper analyzes the relationship between economic activity and the intensity of fighting in the Donbas region of Eastern Ukraine. Due to the conflict as well as political pressure, migration, and the difficulty of obtaining economic metrics, the estimates of economic activity coming from both the Ukrainian-controlled territories and the rebel-controlled territories almost certainly are inaccurate. Therefore, to estimate the economic activity in the region, nighttime satellite images are used. The latter dataset at hand is similar to other papers that have utilized satellite images in estimating economic activity. Examples of these include but are not limited to research done by Bundervoet, Maiyo, and Sanghi (2015), as well as Henderson, Storeygard, and Weil (2012), and Elvidge, Hsu, and Tilottama (2017).

As mentioned in the introduction and literature review, images taken by the Operational Linescan System (OLS) of satellites from the Defense Meteorological Satellite Program (DMPS) are used. There are some disadvantages to using them as they do not correlate exactly to economic activity and, in this case, may not be recording a lot of economic activity that is more unique to Donbas compared to other regions. For example, coal mines and steel plants, in addition to any sort of agriculture, may not be captured by the analysis of nighttime imagery. These activities, however, would translate to other economic activity in the areas that should be captured through this analysis.

This paper uses images of satellites from the Defense Meteorological Satellite Program (DMPS), which were taken using the Operational Linescan System (OLS). The new dataset is called the New Series, and similar to the Original Series, there are some limitations to it. In the Original Series (1992-2013), the main restriction is that the images are usable only if the overpass of the satellite occurred after 19:30 local time (7:30 PM), and using the graph on the extended series from the EOG website, this means anytime starting around 19:12 until 23:20. However, in the New Series, the images are usable only if the overpass occurred before 4:30 local time (4:30 AM), and this means starting around 2:24 up to around 4:48. The reason this difference exists is that, at that point, they had started collecting pre-dawn data. The difference in luminosity between post-sunset data and pre-dawn data should be investigated as an extension of this paper. The limited data set provides yearly and monthly averages from 2013 to 2019. Fortunately, this period is entirely captured by one satellite, F15. Furthermore, for similar reasons, it is assumed that the pre-dawn data's effect on economic activity is similar to the post-sunset data's effect, which is already used in previous studies. As this paper studies changes in economic activity and the full data set captures the pre-dawn data, then the relationship between post-sunset and pre-dawn nightlight images is not necessary to understand the economic activity of Donbas. The important condition is that they should be highly correlated, since 2013 captures the initial conditions.

The DMSP satellites lack an on-board calibration mechanism; therefore, they report the data in digital number (DN) rather than report the values as a radiance. Radiance is a measurement used in radiometry that helps capture the light intensity. The use of radiance would allow for the performance of the research since it can then be converted into light intensity. To perform the intended analysis for the research paper, inter-calibration would be required (conversion from the Digital Number) to carry out the time series analysis (EOG). Many other factors are included to ensure that the images are of the highest quality possible, such as excluding solar and lunar illuminance, glare, seasonal adjustments, in addition to other lights such as gas flares. Each pixel is ranked by luminosity from 0 to 63, with 0 being completely dark, such as an image of a non-lit planting field, and 63 is representative of a well-lit area in a city. These pixels are grouped together into districts of the region or city, called rayoni.[8]

Nonetheless, it is very important to use inter-calibration even when the same satellite is used. This is important for a few reasons such as sensor aging, unwanted light contamination, and relative positions of satellites with regards to the area under investigation. In order to complete an intercalibration between different years, a synthetic region is chosen. This region is assumed to have a constant luminosity throughout the period of study (2013-2019). For the Donbas region, the Sumy Oblast is chosen. While there currently is extreme fighting there, and in hindsight, people would indeed need to be worried about potential fighting in the area, between 2013 and

[8] A word referring to a specific area in this city. It could mean district or county as well. - using Cambridge Dictionary

2019, there was no indication that fighting was escalating. Therefore, people did not make any economic decisions with regards to the events in the Donbas region. The Sumy Oblast is chosen due to its distance from Donbas and its unchanged migration patterns even after the start of the conflict in Donbas. Since Sumy did not experience an exogenous shock, it is a good area to use as a reference. Also, it borders Russia, and it did not undergo a change in migration patterns. The readjustment process happens in the following way:

1. First, a neutral region is chosen, which should have had the true luminosity value stay constant across the years and satellites. In this case, the region of choice is Sumy for the reasons stated previously.
2. Next, the base year is picked based on the highest luminosity values compared to other years. In this case, the region with the highest luminosity values for the Sumy region was 2018.
3. Then a regression is used to find the appropriate conversion coefficients. Sumy's 2018 values are used in the following equation as the dependent variable, and Sumy's values in every other year are used as the independent variable. All this enables the finding of the values of θ_0, θ_1, and θ_2:

$$Luminosity_{2018} = \theta_0 + \theta_1 Luminosity_t + \theta_2 Luminosity_t^2$$

Year	$\widehat{\theta_0}$	$\widehat{\theta_1}$	$\widehat{\theta_2}$
2013	-0.282	1.104	-0.002
2014	-0.190	1.093	-0.001
2015	-0.403	1.370	-0.006
2016	-0.108	1.051	-0.001
2017	-0.102	1.103	-0.001
2018	0.000	1.000	0.000
2019	0.265	0.874	0.001

Table 2, Intercalibration regression results. Donbas luminosity is inserted in *Luminosity*, and luminosity.intercalibrated gives the inter-calibrated values (Source: ArcGIS)

4. After the values for θ_0, θ_1, and θ_2 are estimated. They are plugged into the following equation.

$$Luminosity.intercalibrated_t = \widehat{\theta_0} + \widehat{\theta_1} Luminosity_t + \widehat{\theta_2} Luminosity_t^{\ 2}$$

5. Now, that $\widehat{\theta_0}$, $\widehat{\theta_1}$, and $\widehat{\theta_2}$ are all estimated, it is possible to get the inter-calibrated luminosity values. After eliminating all pixels with luminosity values below 7, the value for each pixel is plugged into the luminosity variable in the equation above to get $Luminosity.intercalibrated$. This value is used in the regressions further.

This $Luminosity.intercalibrated$ term is used in the regressions section of the paper. Luminosity values on their own do not give a representation of how an area has been affected, as some areas are naturally more or less developed and hence luminous; therefore, to understand the effect that the conflict had on the Donbas region, the change in luminosity from year to year is studied in the data analysis section. The latter is done by using the logarithm of luminosity, which in turn reduces heteroskedasticity.

The main challenge with this study is that the war in Donbas is recent and dynamic. The fighting is constant and ongoing, and that the borders could quickly change. Unfortunately, to the experts' belief, this turned out to be true when Russia invaded Ukraine at the end of February 2022. The nature of the conflict makes it difficult to analyze the distance from the border to a town since there are no exact border coordinates to reference. Therefore, approximate borders were replicated according to the areas controlled by the Ukrainian army between 2015 and 2019, prior to the start of the Ukraine/Russia conflict. While these borders cannot be exact since there was still some territory gained or lost by the Ukrainian Armed Forces, this approximation should be accurate for this level of study. The Second-level Administrative Divisions (2015), created by Stanford University and the University of Texas, were used to analyze separate regions controlled by the Ukrainian government and the rebel-controlled regions. Some administrative districts might not match the names of current towns and districts, since, starting in 2016, the Ukrainian government renamed many towns and changed some district borders in response to the ongoing conflict in Donbas. However, this does not affect the analysis.

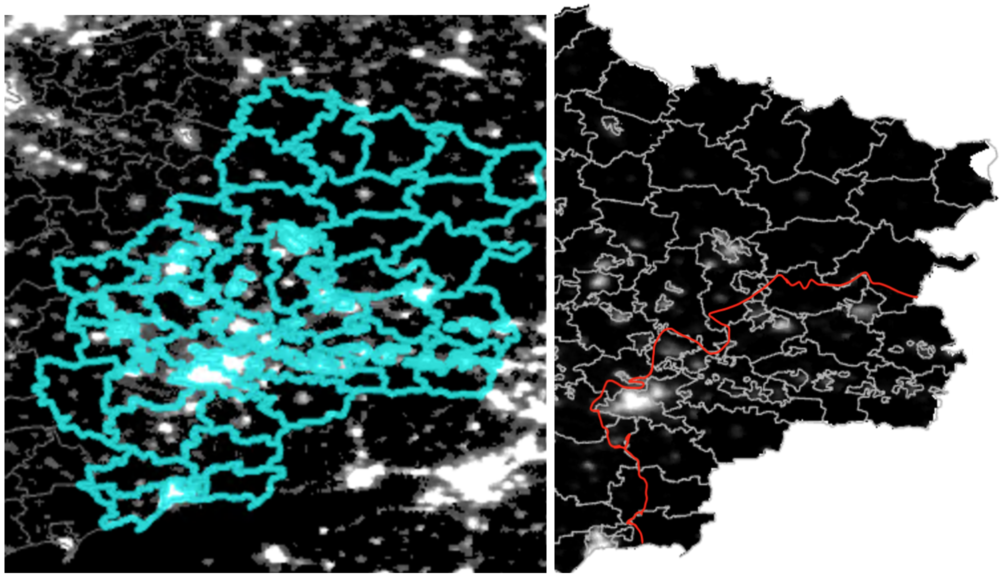

Figure 5 , Nighttime Satellite Image of Eastern Ukraine 2014. Left Image: Donetsk and Luhansk Oblasts. Right image: actual territory under separatist control (Source: ArcGIS EOG Data)

4.2 Intensity of Conflict and other data

The intensity of conflict data are approximated by battle-related deaths similar to the research by Gates et al. (2012) analyzing the effect of conflicts of different severity. The Battle-related deaths were collected by the Uppsala Conflict Data Program (UCDP) in the Department of Peace and Conflict Research. The UCDP program had a lot fewer recorded casualties than state media sources on either side and contained mostly verified reports, therefore, its data database is primarily used. The main challenge with using these data is that many casualties do not have a precise location. Therefore, the casualties that could be mapped to specific districts were mapped manually, and those that could not be mapped precisely were evenly distributed among approximate locations. Both civilian and military casualties were separated to observe the effect of whether civilian casualties would affect the economic activity or migration patterns more than military ones.

Another data source of the presence of fighting is the Organization for Security and Co-operation in Europe (OSCE) and its Special Monitoring Mission to Ukraine. The main objective of this mission is to report on the situation in Ukraine, and throughout its functioning period, the group produced reports that focused on recording cease-fire violations. It has been deployed since 21 March 2014, and its recordings have been used to identify in which administrative districts the shelling took place.[9] The number of violations is not representative of the intensity of the conflict since the presence of shelling in itself means that the conflict is moderately intense. In this case, if an administrative district had medium-to-high levels of violations according to OSCE that particular year, it is given a value of 1 and simply use a binary variable.

Furthermore, another helpful measure that can show approximately the effect of fighting on economic activity is the distance from that particular district to the border of the Ukrainian army- and rebel-controlled territories. There has also been research made on the distance from potential conflict zones and how property rights are affected by that distance. A paper by Acemoglu, Johnson, and Robinson (2000) looks at colonization and the ability for more stable colonies with higher investments in infrastructure to have better economic development in the long term. While the conflict at hand is much more recent than the conflict looked at by Acemoglu et al. (2000), the paper still serves as a great base of what effect investments into properties can have on economic development and hence the limit between light and development. Another research paper that looks at this idea and finds a correlation between the distance of an area to an external threat and the economic development of that area is a paper written by Chad Kalil (2020), which looks at property rights in the Nagorno-Karabakh region. The author studies how the external threat (notably invasion by Azerbaijan) affects economic development through property lights and uses satellite image data in the analysis as well. The approximate distance from the border to the center of that particular district is recorded. It is expected that the farther the district is from the border, the higher the luminosity will be, as it is not under as much of a threat of destruction. However, a differentiating factor in this paper is that the conflict in Donbas is much more dynamic while the conflict in Nagorno-Karabakh was mainly frozen until 2020. The OSCE and UCDP data should supplement this discrepancy.

Additional data are used from the Ukrainian 2001 census, which is the most recent census done. It is assumed that even though the percentage distribution of ethnicity may have changed, the general trends would stay relatively similar to what they were in 2001. A variable is created to measure the difference between the percentage presence of Ukrainians and Russians. The variable first finds the difference between Ukrainian and Russian ethnicities for each

[9] https://www.osce.org/special-monitoring-mission-to-ukraine

administrative district or county. Afterwards, the value for the mean difference between Russian and Ukrainian ethnicities is computed for these counties/districts. To find the deviation from this mean, each county's/district's difference in ethnicities is deducted from the mean difference. Then the absolute value of this *total* difference is used. This value is of significance as we expect less fighting in areas that become all Ukrainian or all Russian. Other ethnicities are usually small minorities with representation of under 10%; therefore, only Ukrainian and Russian ethnicities are considered.

Due to the ongoing conflict that escalated in late February, it was not possible to get access to displaced people records that the Ukrainian government keeps track of. It would be useful to map exactly from which cities most of the people had moved and compare this to what the satellite data is showing. These documents show the migrants' destinations which could be helpful in understanding the economic impact of people being displaced. For example, wealthier displaced persons would be more likely to move to large cities such as Kyiv, Kharkiv, or Odesa. Less wealthy displaced persons would be more likely to move elsewhere in Ukraine where they had family or where the Ukrainian government was offering support with housing, which is usually in smaller towns. The negative effects of wealthier people moving could be higher since they usually take their wealth with them. Unfortunately, without access to these files, the analysis on the micro-level would not be as thorough.

5. Data Analysis

This thesis analyzes the economic situation in rebel areas of Eastern Ukraine on two different levels. First, the paper focuses on analyzing all the administrative centers and rayoni (counties) in the Donbas region. Second, I then focus on specific towns. The following images include parts of Eastern Ukraine showing that the effects that the conflict had on some towns are even visible to the eye. Analysis showed that most often cities/towns exhibited patterns similar to one of the following cities. Horlivka (circled in green or the leftmost figure) - following the initial shock, there was a slow increase in luminosity to lower levels than they were pre-conflict. Alchevsk (encircled in purple or the central figure) - following the initial shock, there was a progressive decline in luminosity. Luhansk (circled in red or the right-most figure) - following the initial shock, there was a return to nearly pre-conflict levels in 2019. As many towns show similar behavior to the ones highlighted below, it was evident that luminosity values (digital numbers represented from 0-63) serve as a good representation of economic activity.

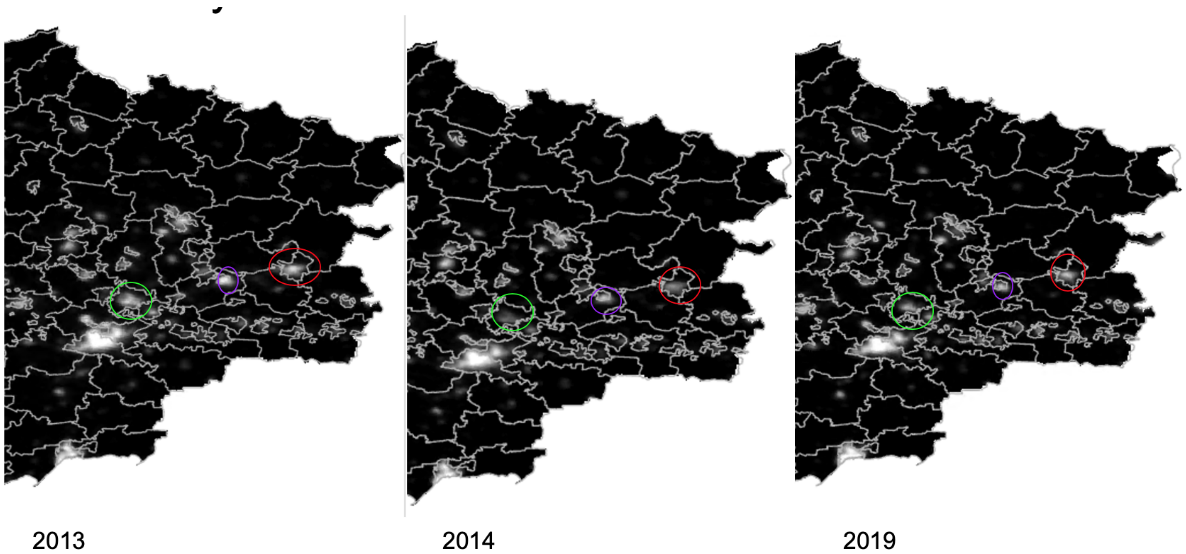

Figure 6, Nighttime Satellite Image of Eastern Ukraine 2013, 2014, and 2019. (Source: ArcGIS EOG Data)

5.1 Average Yearly Nightlight analysis

The following 2-Stage Least Squares time-series model looks at the relationship between the change in luminosity and the intensity of fighting in the Donbas region that is approximated through a number of factors including distance to the border, battle-related deaths, civilian deaths, and OSCE recorded ceasefire violations. The 2SLS model is chosen because the variable for battle-related deaths contains higher inaccuracies and including it could cause omitted variable bias. Deaths and luminosity are likely correlated with the same omitted variables such as civilian fear index. Therefore, including battle related deaths in the OLS would risk omitted variable bias. The Instrumental Variables of CivilianDeaths and OSCE violations are used as instruments for battle-related deaths since Civilian Deaths and OSCE should not correlate with satellite nightlights. That is because they usually result from ongoing fighting or simply from intimidation rather than from an escalation of fighting events. For this particular case, the intensity of fighting is restricted between armed forces; therefore, shelling of civilian areas and cease-fire violations are not considered fighting between armed forces. Rather, shelling of civilian areas and cease-fire violations instill instability on each of the populations but do not necessarily cause nightlights to fall to the extent that battle deaths do. Therefore, the model comes out as follows with Deaths as Instrumented Variable.

Stage 1: $Death_t = \alpha\, D.Civilian_t + \beta\, V + e$

Stage 2:

$$ln(Lum.Aj_t) = \gamma + \delta\, ln(A) + \zeta\, Dist + \vartheta\, Dist^2 + \sigma\, \widehat{Death}_t + \tau\, ln(Lum.Aj_{t-1}) + \phi\, R + \rho\, E + \chi\, Y + \gamma + e$$

Compared to the regular OLS equation:

$$ln(Lum.Aj_t) = \delta\, ln(A) + \zeta\, Dist + \vartheta\, Dist^2 + \sigma\, Death_t + \mu\, D.Civilian_t + \omega\, V + \tau\, ln(Lum.Aj_{t-1}) + \phi\, R + \rho\, E + \chi\, Y + \gamma + e$$

The light intensity for the previous period is included because districts that have higher luminosity values tend to be cities and towns, which in turn largely affects how strong the luminosity changes end up being.

	Coefficient IV	Coefficient OLS	z IV	t OLS
ln(Area) - δ	-0.08272	-0.06111	-2.35*	-1.73
Distance - ζ	-0.01848	-0.00867	-2.70*	-1.50
Distance^2 - ϑ	0.00023	0.00014	3.23*	2.14*
Deaths - σ	0.01513	0.00056	1.71	0.87
Deaths Civilian - μ	–	0.00070	–	0.96
OSCE violations - ω	–	0.16721	–	2.79*
ln(Lum.Adj) for previous year - τ	0.29326	0.28198	6.46**	6.08**
Rebel Controlled - ϕ	-0.15688	-0.07115	-2.11*	-1.30
Ethnicity - ρ	0.00382	0.00376	1.91*	2.13*
Year - χ	0.08067	0.04279	3.80**	2.87*
Constant - γ	-161.160	-84.887	-3.76**	-2.82*

Table 3, Comparison of IV and OLS regression results. Number of Observations: 355

**-significant at 99%, *-significant at 90%

It was anticipated that OSCE violations and Civilian Deaths would not have a direct effect on luminosity, but battle-related deaths that reflect battles happening would more likely have an effect on luminosity changes. However, as it can be seen from the OLS regression, OSCE violations are not a great instrument as they possess certain limitations; therefore, potentially using another variable would be helpful.

The relationships came out mostly as expected. It is important to also include rayon size (ln(Area)) in this regression because larger areas tend to have lower mean luminosities. This value is similar for both OLS and IV regressions. Ultimately, this allows for the isolation of the coefficient of the distance variable and thus allows for the focus to be solely on other variables present.

The Distance surprisingly shows a negative correlation with increased luminosity for both regressions. This does not support the theory that the farther the location is from the border, the less likely people there are to be worried about the armed conflict reaching them. As the distance from the border gets larger, there is a positive correlation with distance from the border. The change of sign happens at about 80.3 km, which is considered to be much farther than what is required to be safe enough from short-range artillery fire. However, just by looking at the map, it becomes clear that the border is not random, and there potentially may have been some planning behind it. Many towns are located right on the border between rebel-controlled territories and Ukraine-controlled territories. Looking at the map of the Donetsk Oblast, some of the towns are circled, but it can be noticed that the large centers, such as Horlivka, Yenakiieve, Donetsk, Volnovakha, Mariupol, and Avdiivka, are located on the border. The situation is similar with Luhansk as well. This may skew the model to show that towns farther from the border have less light, which is not what was previously expected. These results show that there are irregularities in the border structure rather than a causal effect of distance.

There is a marginally positive statistically significant coefficient for battle-related deaths. This was not expected. It could be due to some other endogenous variable affecting the results or due to the time lag. An example of time lag involves people moving away after the occurrence of deaths rather than during the occurrence of deaths. Nonetheless, it is difficult to comprehend why the value came out as positive. The OLS regression coefficient on battle related deaths is not a statistically significant coefficient. It was expected that battle related deaths would have a statistically significant negative coefficient because history shows that many cities in Donbas were founded for industrial purposes, and people moved there to either work at the factories or mines. For example, Donetsk, the regional center and the capital of the de facto country Donetsk People's Republic, was founded by an industrialist named John Hughes, who built a steel plant in the region. Moreover, the region was initially referred to by the founder's name for a few years (Yuzovka). Another example is Yenakiieve, a city that was also founded for metallurgical purposes by a Russian-Belgian metallurgic society. If those mines were not functioning or the work conditions became difficult, then people would likely move out. That is why these results are surprising.

The luminosity of the previous period has a statistically significant coefficient. This turned out as was expected. While the sign of the coefficient might not be comprehensible at first, it is important to realize that the biggest drop in luminosity occured between 2014 and 2015. After that period, many of the towns did recover in terms of economic activity. Therefore, this may be the cause of the positive sign.

There is a marginally negative statistically significant coefficient for rebel-controlled territories. This could be the case because rebel controlled territories are not as well supplied, which could further influence people to move out from rebel areas. The latter would, therefore, explain the negative coefficient. Controlling for endogeneity allowed for the coefficient in the IV regression to be statistically significant.

Furthermore, the coefficient of whether the area had a predominantly Ukrainian or Russian population is statistically significant. This indicates that the more homogeneous the population is, the less likely there will be conflict. Therefore, the recovery is also quicker in those counties. However, it is important to remember that large cities tend to be more heterogeneous, which in turn experience larger drops in luminosity. It would be interesting to further investigate this in another research paper.

A time trend variable is included to capture any other variations in data between the different time periods. It has a positive coefficient due to the fact that after the initial shock, the luminosity began to recover until 2019.

It is also helpful to qualitatively analyze the changes in nightlights in the Donbas region as a whole and understand what could have caused this. Below is the graph of luminosity sum in Donbas. The armed conflicts started in April 2014, and full-scale fighting began in the summer of 2014, after the unrecognized referendum in DPR and LPR. It can be seen that in 2014, the mean luminosity was higher than in 2015 as mean luminosity represents the average of the entire year, and the situation was relatively peaceful at the beginning of that year. Furthermore, most of the migration movements began in mid-2014.

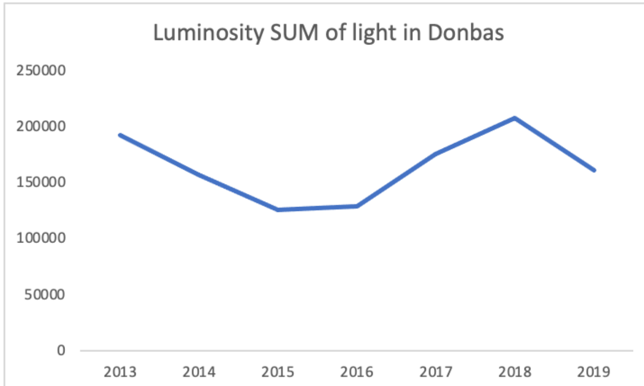

Figure 7, SUM of Luminosities per pixel in the Donbas. (Source: ArcGIS EOG Data)

Paul Collier's (1999) study dives into Civil Wars specifically, which is relevant since the war in Ukraine could be classified as such. Even though there is external support for both sides of the conflict and there are reports of direct intervention, a Civil War study best suits the situation in Ukraine from 2014-2022. Collier finds that generally GDP per capita declines at 2.2% compared to the country's GDP per capita without the Civil War. One of the main things that Collier highlights in his paper is the fact that capital-intensive sectors decline more forcefully relative to the GDP per capita and the dominant industries in Donbas are capital-intensive. There is a big drop in production in these regions for two main reasons: migration patterns and supply shocks. Migration decreases the number of consumers available and reduces the number of potentially skilled employees. Sanctions and border closures create further problems with supply and demand shocks. Donbas coal, which used to be exported to all of Ukraine, is no longer allowed to be exported to the rest of Ukraine. Therefore, it is expected that there will be a large decrease in product demand. As Collier further highlights, there is capital loss due to destruction; many factories and mines located in the bordering regions are no longer functioning. Thus they are not employing people, which should be reflected in the economic activity. Many people in fact do move away from the towns or cities they previously inhabited, which is reflected in the satellite nightlight data.

The later years, from 2016 to 2018, are considered to be the later stages of the conflict during which capital stock adjustments were already made. The years of 2014 and 2015, as this paper would classify, should represent short-term civil war effects or, in this paper's case, early stages of the conflict. They would represent the periods when the capital stock adjustments have not been made yet. Therefore, early on in the conflicts, it is expected for economic activity to fall. In 2016, however, it can be seen that there is a strong recovery in this sector. According to Collier's paper, this is expected; Collier talks about short-term wars having a strong effect at first, but he explains that later on, the capital adjustment is made and industrial production increases.

Another explanation for this drop is related to the high correlation between population and luminosity data in Ukraine. Many wars are known to have significant migration patterns. The war in Donbas is no exception, and around 925,500 people (2.1% of the Ukrainian population and 25% of the Donbas population) sought asylum outside of the region by August 2014. The biggest drop of luminosity SUM can be seen in 2015. There are no records of how many people have moved back to the Donbas region after leaving for the initial period of time. The satellite data show that there is a large segment of the population that does indeed leave in the first two years of the conflict, but then it starts to recover after 2015. Once the violent fighting period subsided, people started moving back into their homes.

In 2018, there were a few terrorist attacks in Donbas, such as the explosion in a cafe that killed the leader of the self-proclaimed DPR. These attacks may have caused some turbulence in the greater Donbas region, which resulted in the slow down of the recovery and even a drop in economic activity. There could be other potential reasons for this such as increased cease-fire violations or a decrease in funding. This issue is further explored on a month-by-month basis.

Figure 8, GDP of Ukraine 2012-2020 (Source: WorldBank data)

There is no yearly/monthly data set of the Donbas region that can be used to accurately represent the economic situation in the region. Ukrainian GDP does show a similar trend to the nightlight data trend between 2013 and 2017. There was no full-scale war in that period of time, but the country was clearly affected by the conflict, as Collier states, due to problems with capital and labor resources. It is possible to make some assumptions based on the satellite images, but nothing can be done with estimating coal or other natural resources' outputs. Assumptions, including that of economic activity, can be made using Collier's (1999) analysis of civil conflicts. The timeline that Collier (1999) offers regarding long and short-term conflicts is clearly correlated with the intensity of the fighting. Usually, the beginning of the conflict is very intense, and as time passes, the conflict winds down. Even if there is ongoing fighting in a long-term conflict, it is important to take Collier's theory into account and understand that the increase in economic activity is coming not only from reduced fighting intensity but also from capital and labor adjustments. The paper by Dreger et al. (2016) calls Donbas a frozen conflict zone, which means that a resolution would need a long time to be achieved. Bluszsz and Valente (2020) did show how fighting affected the Donbas region. Between 2013 and 2016, the GRP of the Donbas region was 47% lower compared to synthetic regions that were created in the paper. Looking at their time-series analysis, it can be seen that the treated economy started recovering in 2015 due to reduced intensity of fighting and capital stock adjustments, which supports the trend seen in satellite imagery.

5.2 Average Monthly Nightlight analysis

$$\Delta ln(Lum_t) = \alpha_0 + \alpha_1 ln(A) + \alpha_2 Distance + \alpha_3 Distance^2 + \alpha_5 R + \alpha_6 E + \alpha_7 Time + \alpha_8 Month$$

This time series regression focuses on analyzing the monthly imagery data. This regression uses the new VIIRS data set, which only recently became available. It provides monthly data with better resolution. In this case, the luminosity from images are processed to be cloud-free. Additionally, more recent data are available with the VIIRS data set. The period for these images ranges from September 2013 to October 2021. Nonetheless, even when the VIIRS data set is used instead of DMSP-OLS, the satellite images on a monthly basis still have missing data. The issue of missing data exists due to the position of the satellite relative to the Earth during a particular month. The satellite takes images of the northern hemisphere, including Ukraine, during the Fall, Winter, and (partially) Spring seasons. Therefore, in this data set, only the months of September, October, November, December, January, February, March, and April are included. Another problem that arises from the difference in the position of the satellite relative to the Earth is the angle at which the image is taken. If the image is taken at a 20 degree angle relative to Ukraine, it records different luminosity values compared to an image taken from a 45 degree angle. As per Elvidge et al (2021), the VIIRS data set does not require calibration. Therefore, a variable is created to show in which month the image was taken in order to offset this issue. This works because during the same month of different years, the satellite should be around the same position. Due to the limited amount of data available, only a time series OLS regression can be done.

There is an additional time treated variable included. This variable tracks when the image was taken relative to the start of the conflict. April 2014 has a value of 0. Images taken prior to that have negative values, and images taken after that have positive values. Other variables, such as Deaths or OSCE cease-fire violations are not included since they are not always available on a monthly basis. However, the variables on who controls the area, the ethnicity, and the distance from the front lines, remain relatively constant; therefore, they are included.

The results of the regression are as follows:

	Coefficient	Std. Err.	t	P>|t|
ln(Area)	0.0066	0.0044	1.51	0.131
Distance	0.0031	0.0014	2.58	0.023
Distance^2	-0.0005	0.0002	-2.92	0.003
Rebel Controlled	0.0017	0.0137	0.12	0.902
Ethnicity	-0.0002	0.0005	-0.48	0.628
Time	-0.0032	0.0003	-12.24	0.000
Months	–	–	–	–
Constant	1.0384	.0512	20.27	0.000

Table 4, Monthly Data Regression Results. Number of Observations: 4155

Some of the results show the expected correlations. For example, the Distance variable, as initially expected, shows a positive correlation with increased luminosity. This supports the theory that the farther the location is from the border, the less likely people there are to be worried about the armed conflict reaching them. As the distance from the border gets to around 6 km, there is a negative correlation with distance from the border. The coefficient on the Distance squared being negative and statistically significant could be due to most of the larger towns being located closer to the center of the Donbas region. Coincidentally, this is where the border along which the rebels and the Ukrainian government are fighting.

The time variable clearly shows that the fighting had a net negative impact on the luminosities of cities in the Donbas region. Luminosity was not able to recover after the conflict, which does make sense considering the fact that the region has been going through constant shelling. While large towns like Donetsk did see some population recovery after the initial shock, this was only because people moved there from other smaller towns around occupied Donbas. Many, who left Donetsk at the beginning of the conflict and moved to areas around Ukraine, did not end up coming back. Additionally, most of the people who were able to move were more educated, with higher average net worths and better earning potential and hence used more electricity. Therefore, solely using the satellite data may not be enough in showing the actual situation on the ground with regards to life stands in the occupied regions.

5.3 Individual Town Analysis

It is also essential to have some qualitative analysis of nightlights in specific towns. These changes are not random and are due to the fact that the town is located in a strategic area or a certain part of town that can be easily shelled. In this case Donetsk, Yenakiieve, and Horlivka, Mariupol, Bakhmut, and Volnovakha are analyzed to see how the nightlights changed throughout the conflict.

a. Yenakiieve administrative district

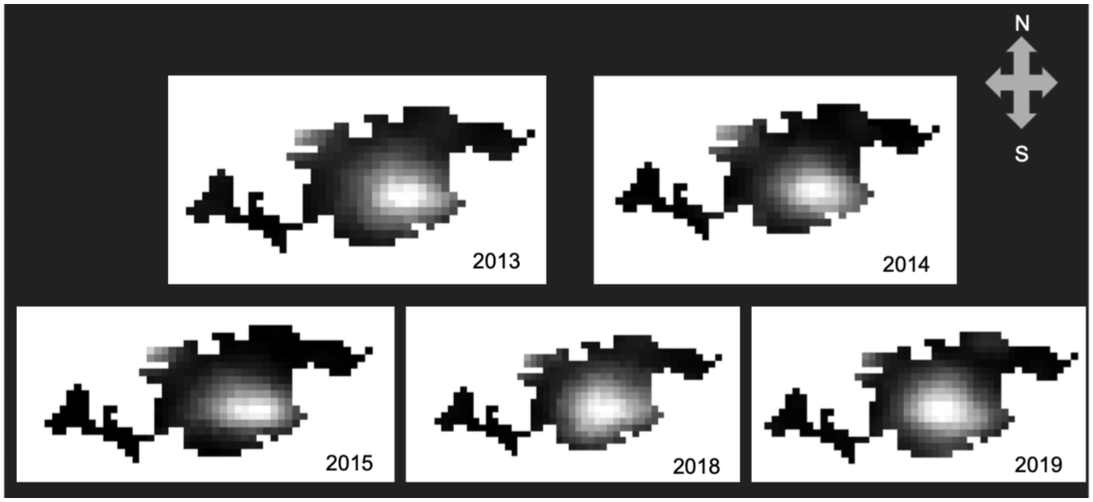

Figure 9, Yenakiieve Yearly Average Nighttime data (Source: EOG Mines)

As it can be seen from the progression of nightlights in the city of Yenakiieve between 2013 and 2019, there is a clear trend that mimics the graph represented. Additionally, the reduction in nightlights in the city is not random. According to battle maps, the city of Yenakiieve had a lot of fighting in the north-eastern part of the city, and it can be seen that nightlight activity there decreased in 2014. Nightlight activity reached its lowest in 2015 and then recovered in 2018, reaching its maximum that year and maintaining strong nightlight activity through 2019. The southern part of the city has a lot of suburbs. Therefore, a reduction of nightlights in that area could suggest that a lot of people moved away from there but then returned later throughout the conflict.

Yenakiieve is currently controlled by the Russian-backed rebels. It has one of the largest metallurgical plants in Ukraine, and the rebel government estimates the population to be at 115,000. The town is located at around 20 km from the border, which is considered relatively close.

b. Horlivka administrative district

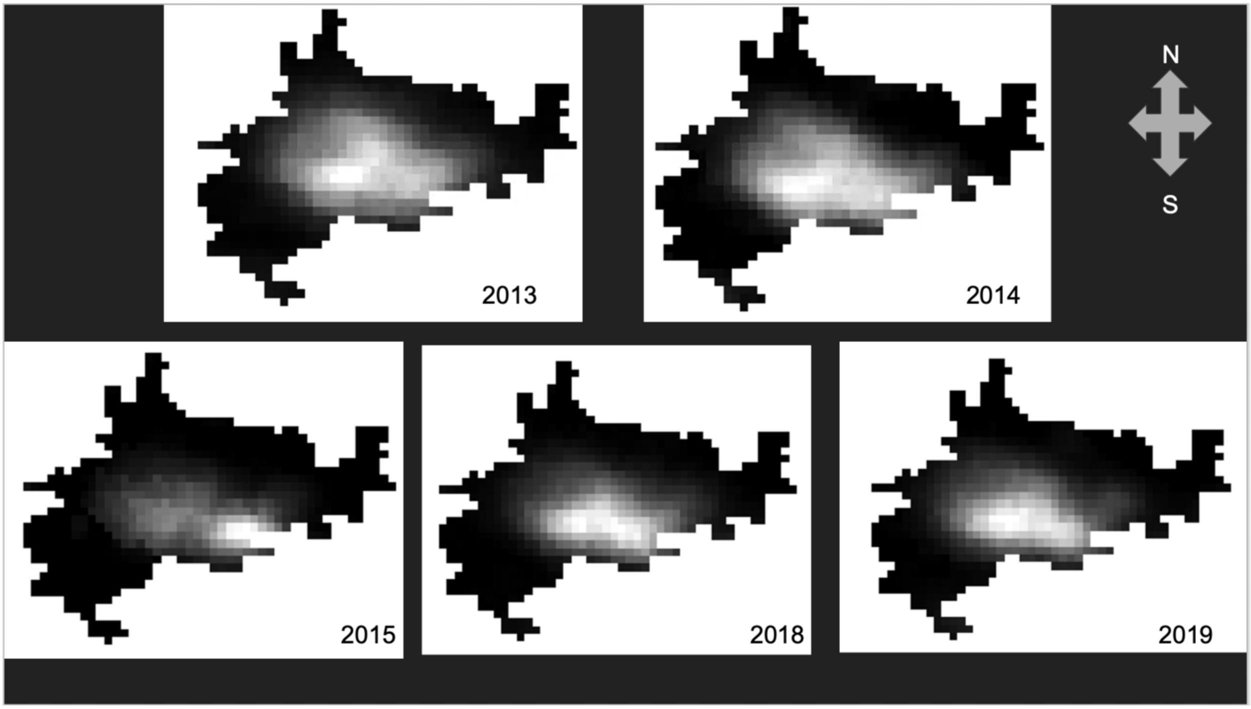

Figure 10, Horlivka Yearly Average Nighttime data (Source: EOG Mines)

A similar situation can be seen in Horlivka, where the year of 2015, in Figure 10, represents the lowest nightlight intensity and precedes a recovery in the coming years. In this case, the drop in nightlights is one of the strongest. Due to this fact, we can deduce from the figure a large presence of fighting around the city in the year of 2015. The city is currently controlled by the rebels. Throughout the conflict, the shelling occurred from the West, North, and North-East. However, in this case, the fighting was so severe that in 2015 Horlivka the loss of nightlight intensity was around -260%. Horlivka is around 5-10 km from the border, which positions it directly on the front lines. As stated previously, the city has strategic importance, as a result, it underwent a lot of fighting. The rebel authorities have estimated Horlivka's population to be 251,651 as of 2021. As media sources state, the population of Horlivka was around 260,000 in 2013. However, using nightlight intensity as an indicator, it seems that population might be lower than the current estimation in 2021. Another explanation could be that due to lower incomes, people's standard of living worsened, which translates to lower electricity consumption. Even after fighting stopped, Horlivka did not recover to its pre-war levels. This could be attributed to many factors, including the possibility of future destruction , low availability of well-paying jobs, and permanent migration to larger cities either within or outside of Donbas.

c. Donetsk administrative district

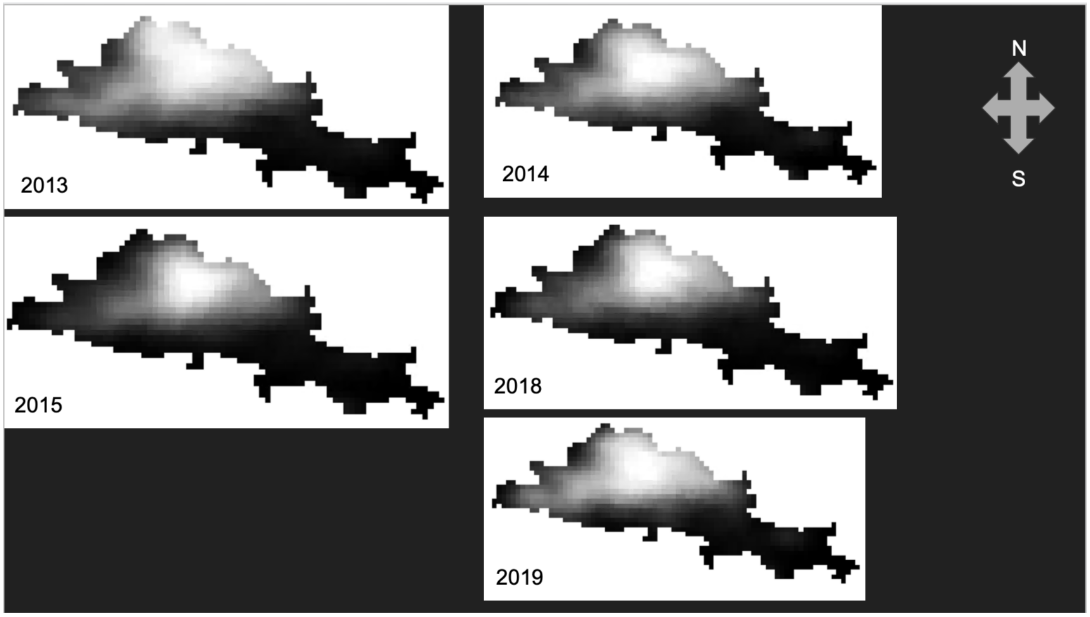

Figure 11, Donetsk Yearly Average Nighttime data (Source: EOG Mines)

Donetsk, as the capital of the self-proclaimed Donetsk Popular Republic, experienced a significant amount of shelling as well. The fighting was mostly happening from the Western side of the city where the airport and some suburbs are located, which can be clearly seen on the map. Donetsk is positioned around 16 km from the front lines, but certain parts of the city still experienced shelling during the period of study. The rebels have estimated the population of Donetsk to be 928,000. This is not that different from what it was prior to the conflict, but the luminosity change from 2013 to 2019 is not that significant, so this number could be accurate. Donetsk's ethnic distribution according to the 2001 census shows that there were 48% Russians and 46% Ukrainians.

d. Mariupol administrative district

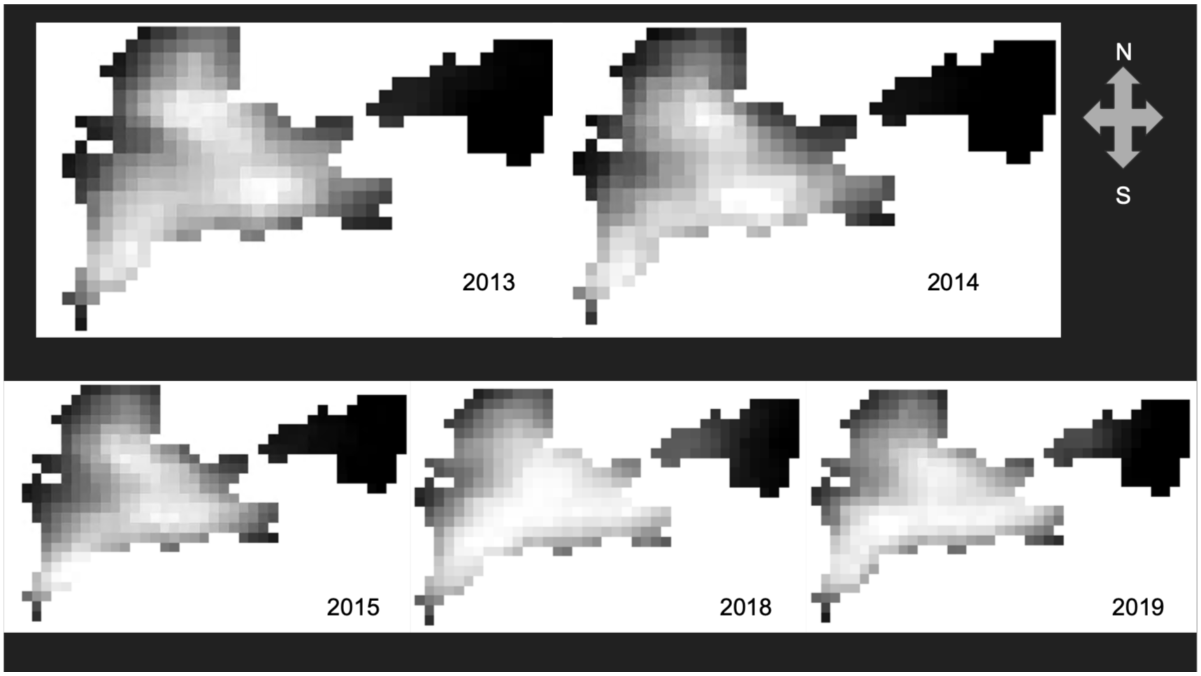

Figure 12, Mariupol Yearly Average Nighttime data (Source: EOG Mines)

Currently Mariupol is experiencing heavy fighting, but for most of the period of the study, it was somewhat peaceful except for a short period of time from May to June 2014. The dip in 2014 was considerably small, and nightlights continue to grow. Even though media sources estimate Mariupol's population to be 440,000 in 2019 compared to 460,000 in 2013, the nightlights in 2019 are higher than the nightlights in 2013, which is counter-intuitive. Mariupol had an overwhelming representation of the Russian speaking population with around 89% calling Russian as their native language. However, it is important to note that one's native language does not necessarily represent their ethnic background. This is especially true for the Donetsk Oblast, where only 48% of ethnically Ukranians called Ukrainian as their native language.[10] After all the recent destruction in Mariupol, the nightlight activity in 2022 will be very minimal. The situation will potentially be similar to Horlivka (2013-2019), but with an even stronger drop in nightlights. Potentially using day-time images and qualitative analysis of reconstruction could also be extremely helpful to understand the economic situation.

[10] Language Distributions for the Donetsk Oblast - from the Ukrainian 2001 census

e. Volnovakha Rayon

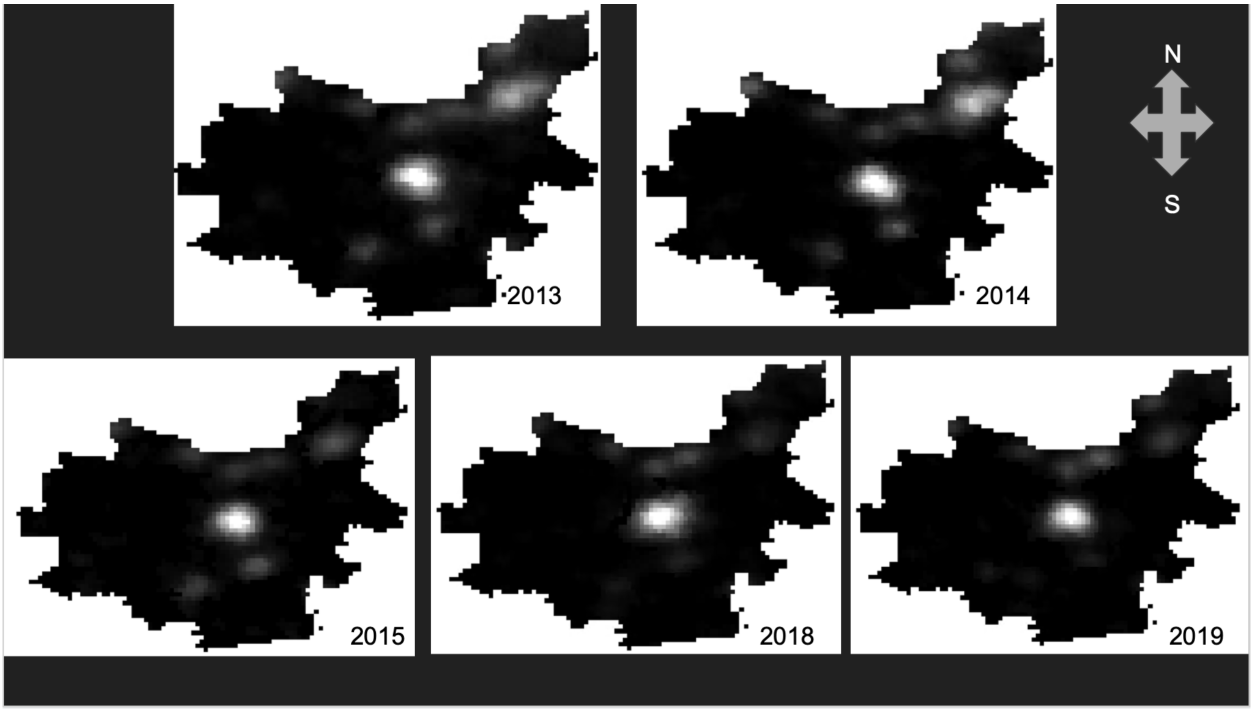

Figure 12, Volnovakha Yearly Average Nighttime data (Source: EOG Mines)

Volnovakha is another town that went through a lot of fighting in 2014/2015 and 2022 - during the time of this research. Initially, in May 2014, the rebels captured the city early in the conflict, but then the Ukrainian army was able to retake control of it in July of that year. The fighting continued even after the cease-fire agreements. Most of the city, however, remained under Ukrainian control throughout the major duration of the conflict. This rayon is on the front line, but the most populated parts of the city are considered to be around 10-15 km from the fighting zones. Most of the fighting that happened in 2015 occured in the North-East side of the rayon. It can be seen from the map that the North-Eastern part of the rayon experiences an almost complete loss of lights at that time. In 2022, the Ukrainian army in Volnovakha went through heavy fighting with the Russian army and rebels. The city is now considered fully destroyed, and has ceased to exist. The Volnovakha nightlights for 2022 will likely look similar to what happened to the North-Eastern side of the rayon. Volnovakha rayon has around 78% Ukrainian population according to the census. Additionally, when analyzing both the city and the county, it is harder to see a strong difference in nightlights, but in this case, the difference is clear.

f. Bakhmut administrative district

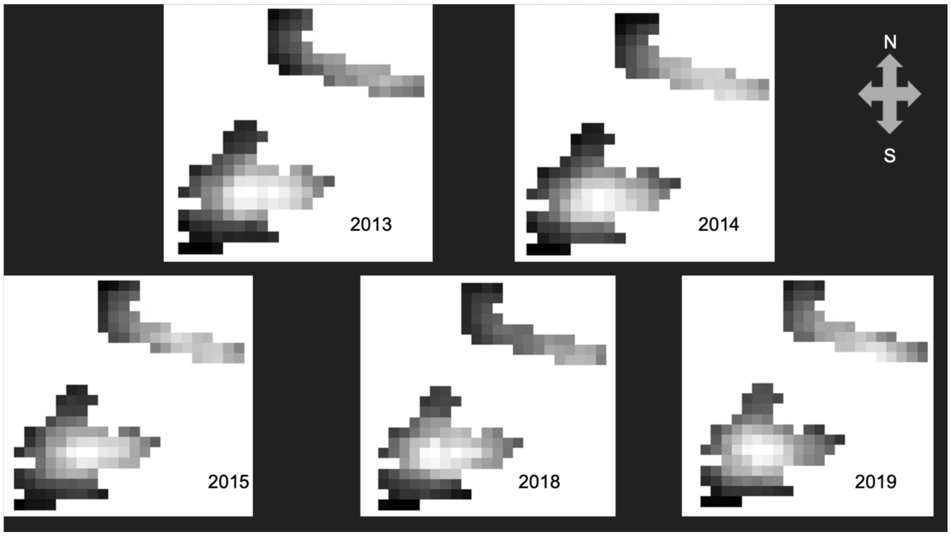

Figure 13, Bakhmut Yearly Average Nighttime data (Source: EOG Mines)

Bakhmut is another town located close to the border where fights with rebels occured. It was controlled by the Ukrainian army for the major duration of the study. In 2016, the city changed its name from Artemivsk, in a decommunization effort by the Ukrainian government. The city was initially controlled by rebels, but the Ukrainian army took control of it in July 2014. The fighting, in this case, happened in the South-Eastern part of the city, which can be seen by a slight reduction in nightlights. The city is around 42 km from the border between the rebel controlled and Ukrainian army controlled areas. At the time of the 2001 census, the city population had around 68% of Ukrainians.

e. Comparisons of changes in different cities and rayoni

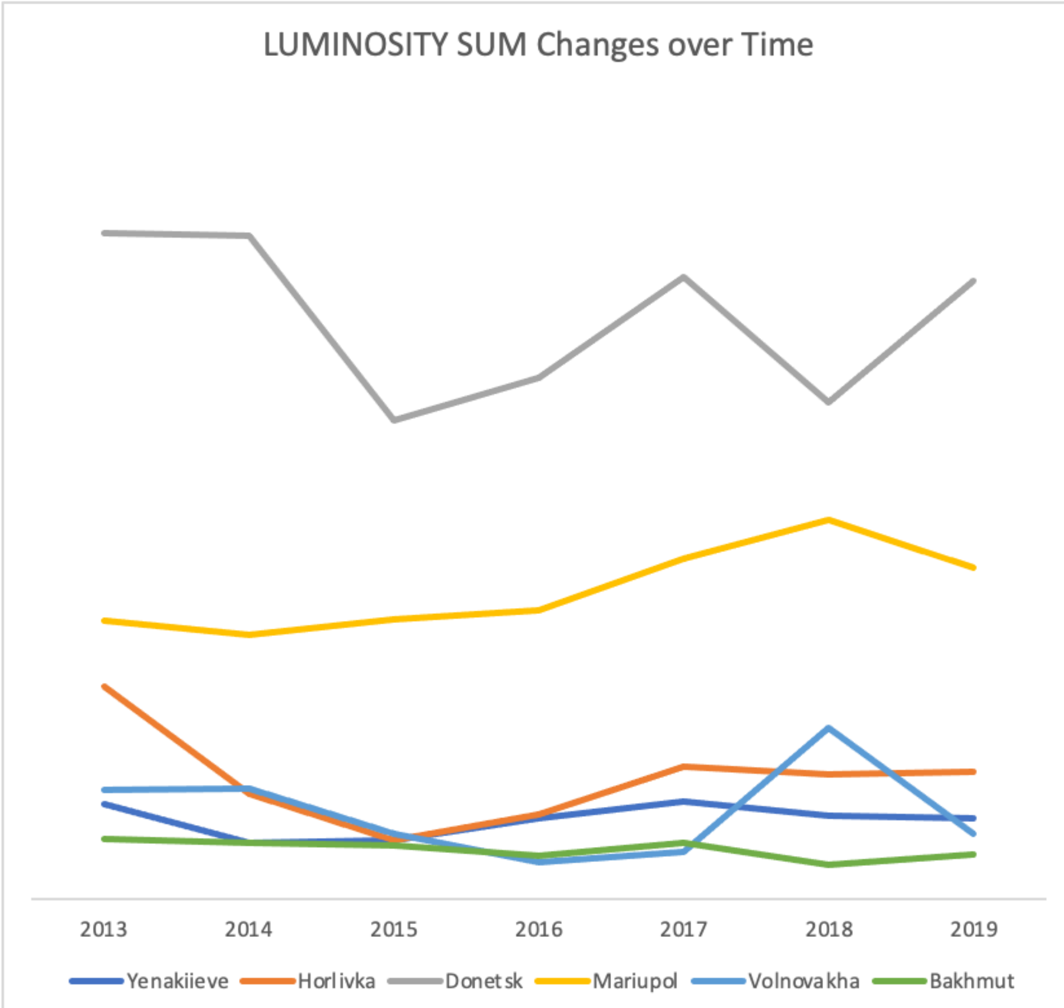

Figure 14, Yearly Average Nighttime data for (Source: EOG Mines)

Luminosity changes observed in Figures 9 through 13 follow a very similar pattern to the graphical changes shown in Figure 14. When analyzing satellite images one can observe the fact that areas which experienced heavy fighting had lower luminosity values as well. This supports the initial hypothesis claiming that heavy fighting has a negative correlation with luminosity levels (or heavy fighting has a positive correlation with reduction in luminosity). What is also worth noticing, is that different towns experienced different changes in nightlights. Donetsk, for instance, stands out due to its relatively large population but the use of SUM of lights - summation of luminosities of each pixel - gives a better representation of changes in the entirety of the area.

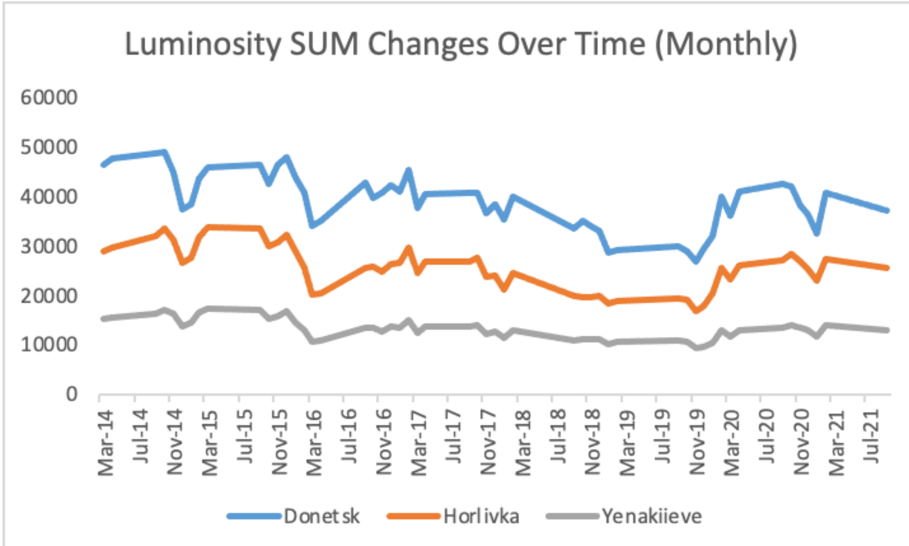

Figure 15, Donetsk, Horlivka, and Yenakiieve Monthly Average Nighttime data (Source: EOG Mines)

The monthly nightlights exhibit many more fluctuations than do the yearly values. The work with the monthly dataset is preliminary and has not been used in this capacity before. Therefore, there could be some differences from the yearly dataset. As stated by Elvidge et al. (2017) VIIRS DNB data set has many improvements compared to the DMSP-OLS including a presence in-flight calibration mechanism. This means that the intercalibration process done for the yearly data is not required to be performed in this case. At the time this paper is written, only the early VIIRS monthly data set is available. According to Elvidge et al. (2021), an annual dataset could be made from using the monthly VIIRS data, and it should be more accurate than the DMSP annual data set. However, these papers do not specify using the dataset on a monthly basis for temporal analysis. From the graph it seems clear that certain months represent troughs and certain months represent peaks, this phenomenon could be possibly attributed to confounding variables such as weather conditions as there is less day-time in the winter which would require increased light usage. Therefore, dummy variables for each month in the regression should solve this issue. As the VIIRS dataset improves, it would be interesting to redo this analysis again to have a better representation of changes on a monthly basis. Overall, monthly nightlights are still relatively new so the results might not be as accurate and give room for larger statistical error than the yearly data.

6. Future Research & Conclusion

6.1 Future Research

This paper provides an updated overview of the conflict in the Donbas region. It incorporates the satellite data into the analysis in order to see whether or not there is any correlation between the drop in satellite nightlight luminosity and distance to the fighting zone. War casualties are analyzed to assess whether they play an effect on lower luminosity. While the conflict has recently escalated into a full-scale Russian invasion, it is still important to understand the ongoing situation in those regions prior to the start of the war.

Therefore, it would be crucial to gain insight into the economic situation in Donbas. Those regions are controlled by non-recognized governments with much less transparency compared to internationally-recognized governments. Future studies can further use the satellite data, especially the VIIRS data set that has monthly values available. The VIIRS dataset is very recent. Elvidge et al (2021) demonstrate its applicability, but it remains a data set that is not established and not yet widely used in research papers. Therefore, as the data set is improved over time, it could contain even more accurate values. Moreover, my research also could be improved with access to the population data from the Ukrainian government. The information on internally displaced people is currently restricted, but if it becomes available in the future, it could help map the changes in nightlights to the changes in population.

Additional improvements can be made on the use of distance from fighting zones. It is possible that not only is the distance important in terms of fighting but also the strategic position of the location. Potentially, elevation could represent the strategic location. However, other indicators could be even more important, such as location relative to other towns. For example, the people in Horlivka are in much more danger than the people in Volnovakha. While both towns are at about the same distance from the fighting, Horlivka serves as a connecting town between the two rebel-controlled territories. Therefore, the Ukrainian army would always want to recapture it, and the same would hold true for the rebels. Taking the strategic location of towns into account could improve the research's accuracy.

The violence of the conflict could also be measured on a monthly basis. The battle-related deaths and civilian deaths are not always mapped to a specific location, especially when deaths are reported individually, on a monthly basis. Therefore, by using these data in addition to monthly OSCE cease-fire violations, a new data set could be created to better represent the violence of the conflict. Furthermore, using the principal component analysis could help reduce the biases of the regressions by combining several highly correlated factors into a single term

6.2 Conclusion

The war between the Ukrainian government and the rebels brought a lot of destruction to the region of Donbas, a region that is heavily reliant on its industrial sector. Additionally, the violent conflict caused vast migration not only to other regions of Ukraine but also to abroad. Donbas was growing prior to the conflict. Many cities there had received many positive awards, such as Donetsk's award for best city for business in Ukraine in 2012, but the war reduced the economic opportunities. The findings do show that there was a significant drop in nightlights at the beginning of the conflict, but they also show that nightlights started to recover after the Minsk peace agreements were signed. Unfortunately for the people in the Donbas region, the recovery was not nearly enough, and the living standards in Donbas fell significantly relative to pre-war values. Because of the conflict, importing goods became much more difficult as there were trading issues between the Ukrainian government and the rebels.

This research could be applicable on a larger scale as well. Prior to the Russian invasion of Ukraine, the conflict in Donbas was the largest conflict in 21st century Europe. The Donbas conflict is not only very recent, but it has been ongoing on Ukrainian territory. If the Russian war in Ukraine results in a stealmate, similar to the one that happened in Donbas in early 2016, further research on the Donbas region could show what trends can be expected from the Ukrainian economy or the Ukrainian people. As per Perelli-Harris (2022), the people who left the Donbas region had a tough time adjusting. With many more Ukrainians migrating in 2022, the situation will be far worse. Additionally, the research could also be applicable to other frozen conflicts. While the research would not be using the casualty numbers, distance from the border could be used to study the drop in economic activity in relation to property rights similar to Acemoglu, Johnson, and Robinson (2000) or Kalil (2020).

It is difficult to make predictions of what will happen to different towns in Ukraine after the current conflict. As it can be seen from what happened in Donbas from 2013-2019, the nightlight development of a particular town after strong fighting highly depends on the location of this town and its strategic importance. For example, Mariupol might have gone through a lot of destruction, but it is the largest port city in the rebel controlled areas. Therefore, if the city were not under the threat of potential destruction, it is very likely that the city would be rebuilt slowly. However, it might take a long time until it comes back to light levels similar to that present in 2021. Towns that experienced heavy fighting could develop similarly to strategically important cities in Donbas. For example, Irpin could experience a similar outcome to Horlivka. However, as the fighting leaves the Kyiv region, the recovery in cities around Kyiv could be much faster.

Other towns, such as Volnovakha that suffered destruction in 2014 and extreme destruction in 2022, will have a tough time returning to previous nightlight levels. Even after rebuilding, it is unlikely that those towns will return to strong growth. The results could be similar to what is present in the North-East of the Volnovakha rayon but on a larger scale. It is also possible to predict what might happen now outside of the Donbas region, for example, in large captured cities such as Kherson. If the city will remain captured for a long time like some cities in Eastern Ukraine, Kherson will likely experience a similar trend. There could be a parallel drawn between Kherson and Donetsk, where initially there will be a shock where the nightlights will drop significantly. However, as the conflict progresses and becomes a long term conflict - as defined by Collier (1999) - then people would move from smaller towns to Kherson with labor and capital stock adjustments happening. Nonetheless, it is difficult to find a general trend as Ukraine is such a large and diverse country. As a result, the analysis for this would need to be town-specific.

The results do support the hypothesis that the conflict has a negative effect on the economies of the region, showing the strongest drop in nightlights between 2014 and 2015. Additionally, some of the data supports the hypothesis that more ethnically homogenous districts experience faster nightlight recovery. Further research could advance the understanding of the situation in Donbas and Ukraine as a whole.

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Appendix

1. Correlation between OSCE, Deaths, and Civilian Deaths

	OSCE	Deaths	Civilian Deaths
OSCE	1.000		
Deaths	0.136	1.000	
Civilian Deaths	0.129	0.099	1.000

Table 1, Correlation between OSCE cease-fire violations, Battle related Deaths, and Civilian Deaths

2. Regression using change in ln($Distance^2$) instead of Distance and $Distance^2$ - Yearly

$$ln(Lum.Aj_t) = \delta\, ln(A) + \vartheta\, ln(Dist^2) + \sigma\, Death_t + \mu\, D.Civilian_t +$$
$$+ \omega\, V + \tau\, ln(Lum.Aj_{t-1}) + \phi\, R + \rho\, E + \chi Y + \gamma + e$$

	Coefficient	Std. Err.	t	P>|t|
ln(Area)	-0.06083	0.03549	-1.71	0.087
ln($Distance^2$)	0.00283	0.02256	-1.26	0.210
Deaths	0.00050	0.00063	-0.78	0.433
Civilian Deaths	0.00064	0.00080	-0.80	0.426
Violations(OSCE)	0.17438	0.23482	-1.65	0.101
ln(Luminosity.Adj for previous year)	0.26505	0.01989	3.98	0.000**
Rebel Controlled	-0.09435	0.05422	-1.74	0.083
Ethnicity	0.00376	0.00173	2.18	0.030*
Year	0.03855	0.15470	2.49	0.013*
Constant	-76.547	31.261	-2.45	0.015*

Table 2, Regression results for Year nightlight data. Obs: 355 **-significant at 99%, *-significant at 90%

There is a positive correlation between distance and luminosity in this case. Potentially using the ln($Distance^2$) is a more appropriate metric. Additionally, in this case OSCE violations are less statistically significant, proving the assumption we had.

3. Ukraine 2014 DMSP-OLS nightlight image

Figure 1, Nighttime Satellite Image of Ukraine 2014

4. Ukraine 2014 DMSP-OLS nightlight image

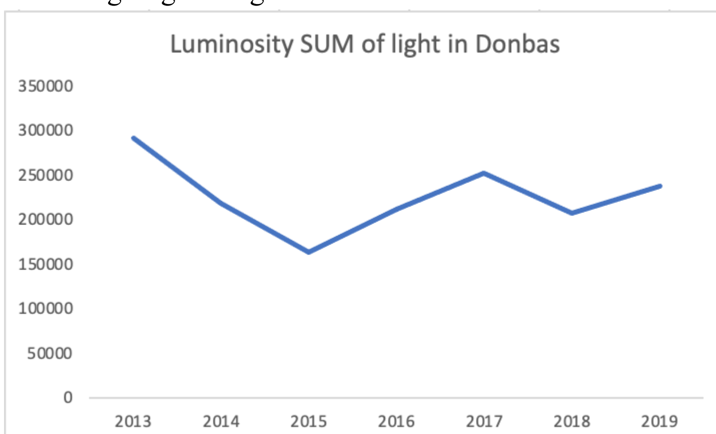

Figure 2, non-calibrated SUM of Luminosities per pixel in the Donbas. (Source: ArcGIS EOG Data)

5. Sloviansk

In this case, the drop in nightlights is not as strong. First of all, when analyzing both the city and the county, it is harder to see a strong difference in nightlights. Even though there was a significant amount of fighting at the beginning of the war in Sloviansk, the city is located around 45 km away from the fighting zone.

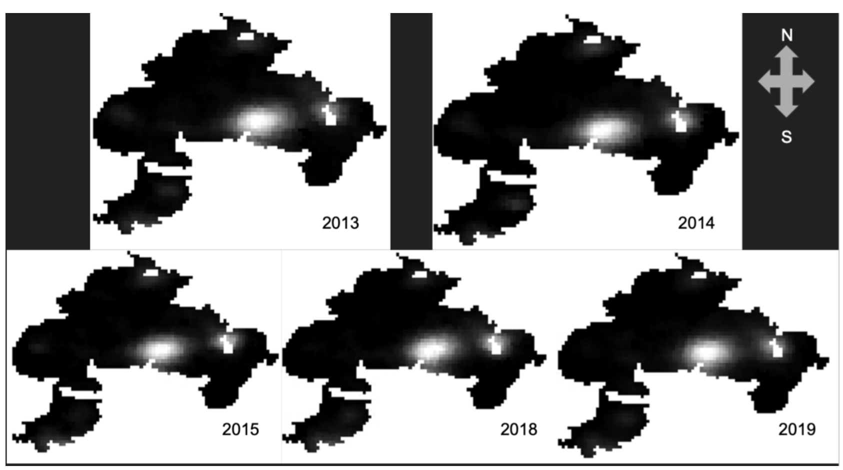

Figure 3, Sloviansk town and county Yearly Average Nighttime data (Source: EOG Mines)

6. Regression using change in ln(Distance^2) instead of Distance and Distance^2 - Monthly

$$\Delta ln(Lum_t) \ = \ \alpha_0 + \alpha_1 ln(A) \ \ + \alpha_3 \, ln(Distance^2) + \alpha_5 R \ + \alpha_6 E \ + \ \alpha_7 Time \ + \alpha_8 Month$$

	Coefficient	Std. Err.	t	P>|t|
ln(Area)	0.0019	0.0042	0.44	0.658
Distance^2	-0.0087	0.0051	-1.68	0.094
Rebel Controlled	0.0036	0.0138	0.26	0.796
Ethnicity	-0.0001	0.0047	-0.19	0.847
Time	-0.0032	0.0003	-12.21	0.000
Months	–	–	–	–
Constant	1.1109	0.0584	19.02	0.000

Table 3, Monthly Data Regression Results. Number of Observations: 4155 **-significant at 99%, *-significant at 90%

In this case the results are slightly contradicting. This could be due to the same issue as previously.