ARMED CONFLICT AND FIRM PERFORMANCE IN DONBAS: WHEN (WHETHER) THE REVIVAL STARTED?

by

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Abstract

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This thesis studies the effect of an armed conflict on total factor productivity (TFP) of firms in Donetsk and Luhansk regions of Ukraine and its evolution. We estimated TFP separately for 18 industries using dynamic system GMM regressions with endogenous factors of production, based on financial reports of a large sample of firms from all regions of Ukraine over the period from 2012 to 2018. The effect of violence was measured using the average distance between the firms and points of shelling, intensity of shelling at each point, and an own designed index accounting for both distance and intensity. While controlling for industry, size and individual firm effect, we found a statistically significant evidence for the negative relationship between each measure of violence and TFP over the period from 2014 to 2018.

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Chapter 1

INTRODUCTION

It was violence that let strong and unproductive ones to get the power over weak and productive others, which in turn led to the emergence of a centralized state in the ancient times and its further transformation in a democratic society as Collier mentions in his online course "From Poverty to Prosperity: Understanding Economic Development"[1]. However, even in the modern world, there are countries currently suffering from armed conflicts. Their economic consequences are subject to numerous papers, but empirical firm-level research is scarce. This thesis is intended to contribute to the literature with the microeconomic evidence from Ukraine, an Eastern European country that has been suffering from armed conflict in its eastern part since 2014.

1.1. Conflict details

In 2013-2014 the political climate in Ukraine experienced an abrupt change due to three unexpected events. The first one was the Revolution of Dignity, a series of protests in response to the violent dispersals of the rally in the country capital, Kyiv, which took lives of about a hundred of people, and resulted in the dissolution of government, ousting of the pro-Russian president Yanukovich and his gateway to Russia.

After that Russian soldiers without military insignia entered the Crimea, the southern region of Ukraine, and conducted a referendum according to which

[1] https://courses.edx.org/courses/course-v1:OxfordX+OXBSG01x+3T2019/course/

Crimea was annexed by the Russian Federation. However, Ukraine and 114 other member states of the United Nations did not officially recognize Crimea as the part of the Russian Federation. For that Russia was suspended from The Group of Eight and imposed with international sanctions.

Despite the sanctions, the third event in this sequence was the formation of two self-declared states by pro-Russian separatists in the Donbas region, which is an unofficial name for Donetsk and Luhansk regions of Ukraine. Rebels occupied government buildings and the Ukrainian government began an anti-terrorist operation against them, which is known as War in Donbas. As of May 2020, the armed conflict is still active. Russian official position is to call it a civil war, but evidence shows that Russia supports the rebels by supplying them with soldiers, military equipment including weapons, tanks, artillery, as well as with food and other necessities.

The number of casualties related to the conflict is estimated to be over 40,000, out of which over 13,000 died including at least 3,350 civilians (according to Report on the human rights situation in Ukraine 2020 by UN Human Rights Council[2]). About 600,000 people suffered from infrastructure damage and a worsened economic environment including access to schools, workplaces, and water[3]. Also, as of May, 2020, more than 1,400,000 people were internally displaced from Crimea and Donbas according to the Ministry of Social Policy of Ukraine[4].

Given the unstable political situation, the GDP per capita in Ukraine fall by 1.2% and 9.4% in real terms in 2014 and 2015 respectively after four subsequent years

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2 https://www.ohchr.org/Documents/Countries/UA/29thReportUkraine_EN.pdf

3 https://www.ohchr.org/en/NewsEvents/Pages/DisplayNews.aspx?NewsID=23320&LangID=E

4 https://www.msp.gov.ua/news/18640.html

of growth, and exports dropped by about 15% and 13% in real terms, mostly driven by a decrease in the share of exports to aggressor country. Unemployment grew by about 2% in 2014 and 2015 compared to 2013, the national currency depreciated about 3 times during the first two years of conflict, and consumer prices rose by 48% in 2015 reaching the highest change over the past 15 years[5].

1.2. Research question

Starting from 2014 the performance of Ukrainian firms was challenged by not only worsened macroeconomic conditions but also by violent actions. The intuition is that violence has both a direct negative effect in the form of takeovers and physical damage and an indirect one arising from expectations, counterparties, and infrastructure being affected. This leads to a number of questions, which were addressed in this thesis:

1. Methodological questions: "How to measure the level of violence experienced by a firm?", "How to estimate the effect of violence on firm performance", and "How to observe its evolution?"
2. Empirical questions: "Is the effect of War in Donbas on firm performance negative and statistically significant?", and "Is there evidence for firms getting adapted to it?"

The only empirical work studying the effect of armed conflict in Donbas on the performance of firms was conducted by Voronin (2019), who found a significant effect of the war on TFP of manufacturing firms and showed that it decreases in the distance from the firm to the demarcation line. He also observed that this

[5] https://data.worldbank.org/country/ukraine

effect vanished in 2016 and interpreted this finding as "an adaptation of firms to adverse condition".

This research is aimed to check the robustness of Voronin's (2019) findings by addressing the same question, but using a methodology which is different due to at least four reasons. First, we estimated production function using system GMM estimator assuming that output depends on its previous period values and that factors of production are endogenous, but not OLS estimates with endogenous as in (Voronin 2019). Second, we designed a new measure of the violence as an index accounting for both the distance and intensity of places of violence. Third, we introduced a set of control variables and accounted for firm fixed effect in the model estimating the effect of violence, unlike the predecessor Fourth, we utilized two more years of data and did not exclude the firms from non-manufacturing industries and those not located in cities.

The two hypotheses are as follows:

1. War in Donbas has a negative effect on TFP of firms in the region, which increases in proximity to points of shelling and decreases in distance to those points.

2. The negative effect of the War in Donbas on TFP of firms in the region weakens over time because of firm adaptation.

3. Thesis outline

The structure of this draft paper is the following: Chapter 2 reviews the empirical microeconomic literature concerning the effects of the armed conflicts; Chapter 3 is dedicated to our methodology description including subsections on the calculation of measures of violence, production function estimation, and regression modeling; Chapter 4 is the description of the initial dataset and its cleaning procedure, and contains subsections for financial statements and violence data; Chapter 5 provides estimates of TFP, several measures of violence, and regression results; and Chapter 6 presents the conclusion and prospects for further research.

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LITERATURE REVIEW

The effects of military conflicts on the economy have been subject to discussion for scientists for many years and there is extensive macro-level research on the impact of wars on economic growth, investments, consumption, poverty, education, and other aggregated variables. Besides, there are opinions and evidence for both positive and negative effects of wars. But the related empirical papers based on the firm-level data are scarce and the findings of the most important ones are discussed below.

Collier and Duponchell (2010) found no significant effect of war, measured as a households survey score, in Sierra Leone over 1991-2002 on the existence of firms and employment at a regional level, but found a negative effect of the intensity of conflict on firm size and income, and a positive effect on willingness to invest in training of employees and the probability that firm faces financing constraints. This let them support the hypothesis that war results in the loss of human capital stock and recommend post-conflict governments to prioritize the training of workers.

Petracco and Scheweiger (2012) discovered that the armed conflict between Georgia and Russia in 2008, despite lasting only five days, affected exports, sales, and employment of firms, but the effect was not the same in the direction and extent for firms of different size and age. For example, the productivity of young firms decreased, while one of the small, medium, and old firms increased in the conflict intensity, which was measured in two ways: as a dummy of the fact of being bombed, and as a number of bombing attacks. Also, the authors used an instrument to control for financial crisis vulnerability, since it coincided with the war.

Camacho, Adriana, and Rodriguez (2013) found that armed conflict raised the probability of the firm exits in Columbia in 1993-2004 by modeling it as a function of the value-added by the firm production, the wage paid to workers, investment, and a number of attacks during the year as a measure of violence, while also controlling for municipal characteristics, year and plant fixed effects, and reducing endogeneity using lagged government deterrence measures as a number of antinarcotics operations and number of drug laboratories dismantled an instrumental variables. They also found that the probability of firm exit is affected to a higher extent when a violent attack is directed towards capital and infrastructure rather than random attacks.

The most closely related work is by Voronin (2019), who found a significant negative effect of the distance from the Donbas frontline on the total factor productivity (TFP) of big Ukrainian manufacturing firms based on their balance sheets and income statements over the period from 2010 till 2016. He estimated TFP as a residual from the fixed effect regression of output on two factors of production: labor and capital, and run a regression of TFP on TFP while controlling for the distance dummy. The obtained coefficient on the distance dummy, indicating whether the firm stands in the 25, 50 or 100 km area from the frontline, was negative and significant thus implying an inverse relationship between the war and the productivity of Ukrainian firms. Besides, using the difference-in-difference estimator, he showed that this effect disappeared in 2016 and concluded that firms' performance does not substantially suffer from the conflict since then.

Another paper related to the effect of war on productivity is by Klapper, Richmond, and Tran (2015), who found the drop in the firm total factor productivity from the civil conflict in Cote d'Ivoire based on the firm-level data for 1998-2003. They estimated the production function using ACF (2006) approach and predicted the TFP as a residual. In addition, the authors found that TFP inversely depends on whether there are foreign workers or foreign capital in the firm.

Chapter 3

METHODOLOGY

3.1. Measures of violence

We designed a unique index of violence, which accounts for the effect of war in a different way than was done by previous researchers, who used one of the following: a dummy indicating the firm's belonging to a certain territory, a distance to the point of violence, or a number of attacks. Our index is supposed to be more efficient since it accounts for both conflict proximity and intensity thus representing more features of violence. Both proximity and intensity can potentially affect business through the influence on clients, counterparties and employees, deterioration of infrastructure, risk of suffering an attack or occupation etc.

The suggested formula of violence index for each firm *i* in year *t* is as follows:

$$Index_{i,t} = \sum_{n=1}^{N_t} \frac{F_{n,t}}{(D_{n,t})^m}, \tag{1}$$

where N_t is the total number of shelling points in period *t*, $F_{n,t}$ is the frequency of shelling at point *n* and year *t* measured in numbers of shelling during the year, $D_{n,t}$ is the distance to the shelling point *n* and year *t*, and *m* is a constant showing the relative weight of $D_{n,t}$.

The opportunity to test different values of m increases the flexibility of the index and allows to change the weight of distance and intensity. If the value of m is higher than 1, the effect of points of shelling located farther from the firm will be weakened due to increased denominators in the ratios which correspond to more distant points.

A desirable feature of the index is that more distant points of shelling contribute less to its value as well as points with lower intensity of shelling relative to the points of shelling which are closer and have a higher intensity of violence. However, an assumption on the maximum distance can be imposed to guarantee that the effect of points located outside a certain area around the firm will be completely ignored.

Also, given that shelling can occur in the same location where the firm is situated, an additional assumption of setting distance from the firm to the point of shelling to a number different from zero is necessary to avoid undefined values of index. In this research, we assumed a distance of 1 km for the pairs of such firms and points of shelling.

The limitation of the suggested violence index lies in the lack of intuitive explanation of its value for a certain firm. It can only be interpreted as a relative measure of violence, and directly used to compare the effect between the firms in the same or different years, or observe its relative dynamics for the same firm in different years. The higher the value of the index, the higher degree of violence is experienced by the firm.

On the contrary, the measures of violence with more comfortable interpretability could be the sum of nominators (2) and denominators (3) of the index of violence separately. The former is simply the number of all cases of shelling in a certain year, and the latter is the aggregated number of kilometers from the firm to all points of shelling.

$$Fre_{i,t} = \sum_{n=1}^{N_t} F_{n,t} \tag{2}$$

$$Dis_{i,t} = \sum_{n=1}^{N_t} D_{n,t} \tag{3}$$

It would be reasonable to restrict the area around each firm before estimating (2), otherwise, the measure will be the same for each firm in a given year and could not be included as an independent variable in a regression model. The measure is increasing in both the number of cases of shelling and number of points, therefore it has a clear direct relationship with violence in the area. On the contrary, there is little sense to impose the same restriction in (3), because doing so would make the measure increasing not only in distance but also in the number of points of shelling in the area. This makes (3) meaningless because it would not be clear whether the estimated value of (3) is higher for a certain firm due to distancing from violence or due to a larger number of points of violence in the area. In order to make (3) comparable for observations in different time periods, it should be prevented from the property to increase in the number of points, for example, by calculating the average distance from a firm to the points of shelling:

$$AvDis_{i,t} = \frac{\sum_{n=1}^{N_t} D_{n,t}}{N_t} \quad (4)$$

3.2. Production function and TFP

The production function was estimated using two-step system GMM approach following (Arellano and Bover 1995) and (Blundell and Bond 1998) since assumptions, under which it is efficient, fit our case of a dynamic panel with small number of periods and large number of observations, endogenous variables, expected dependence of firm output on its historical values, fixed individual effect, and heteroskedasticity.

As dependent variable firm revenues were used, and independent variables included current values and first lags of capital and labor, and year dummies. We decided to measure capital and labor inputs as net values of property, plant and equipment (PP&E) and number of employees respectively. The first lags of both independent variable and production inputs were included as endogenous GMM style instruments, and year dummies were used as endogenous instruments only in the level equation following Roodman (2009).

We estimated the production functions separately for each industry according to classification by the State Classifier of Ukraine ДК 009:2010. The total factor productivity (TFP) was estimated as a sum of intercept, which reflects the average productivity in the sector, and residual showing the firm deviation in productivity from the industry average.

3.3. Effect of war

The first hypothesis is that the armed conflict in Donbas has a negative effect on TFP of the firms in the region and we designed the following model to test it:

$$Y_{i,t} = a_1 + a_2 Index_{i,t} + a_3 Year_{i,t} + a_4 Industry_{i,t} + a_5 Size_{i,t} + e_{i,t}, \quad (5)$$

where $Y_{i,t}$ is the TFP, $Index_{i,t}$ is the violence index estimated according to (1), $Year_{i,t}$ is the set of dummies for each year, $Industry_{i,t}$ and $Size_{i,t}$ are the control variables representing a set of dummies for each industry and firm size respectively. The coefficient of interest in this model is a_2, whose significant negative value would support our hypothesis, showing that the dependent variable is decreasing in the measure of violence. The intersection between control variables should also be included when a firm individual effect is not fixed.

Also, in order to decompose the effect of violence into distance and intensity components, the index of violence in the model (5) could be substituted for estimated (2) and (4), which results in the following specification:

$$Y_{i,t} = a_1 + a_2 Dis_{i,t} + a_3 Fre_{i,t} + a_4 Year_{i,t} + a_5 Industry_{i,t} + a_6 Size_{i,t} + e_{i,t}, \quad (6)$$

Where $Dis_{i,t}$ is the sum of distances from the firm *i* to each point of shelling in period *t*, and $Fre_{i,t}$ is the number of cases of shelling in a certain area around firm *i* in period *t*. In this model, we expect to get a positive a_2 and a negative a_3, evidencing that higher distancing from shelling is associated with a positive effect on TFP, while more frequent shelling has a negative one.

Finally, we would like to observe the evolution of the violent effect to test the second hypothesis, which becomes possible by extending models (5) and (6) with the interaction terms between year dummies and violence measures, ending up with two following specifications:

$$Y_{i,t} = a_1 + a_2 Index_{i,t} + a_3 Year_{i,t} + a_4 Index_{i,t} Year_{i,t} \\ + a_5 Industry_{i,t} + a_6 Size_{i,t} + e_{i,t} \tag{7}$$

$$Y_{i,t} = a_1 + a_2 AvDis_{i,t} + a_3 Fre_{i,t} + a_4 Dis_{i,t} Year_{i,t} + a_5 Fre_{i,t} Year_{i,t} \\ + a_6 Year_{i,t} + a_7 Industry_{i,t} + a_8 Size_{i,t} + e_{i,t} \tag{8}$$

The signs of estimated elements of vector a_4 in (7), and a_4, a_5 in (8) would show the changes in the effect of armed conflict on the dependent variable in the respective years compared to the base year. Also, these are the models (7) and (8), which enable us to test whether the negative effect of the War in Donbas on TFP vanished in 2016 as concluded by Voronin (2019).

Chapter 4

DATA

4.1. Financial statements

The first part of the dataset is an unbalanced panel of 517,163 Ukrainian firms containing 2,243,782 observations of items from Balance Sheets and Income statements. It unites both small and big firms from all industries and all regions of Ukraine over the period from 2011 to 2018.

For the goal of this research 11 variables were extracted from the financial statements: year, firm identifier, territory code (according to State Classifier of Objects of Administrative and Territorial Structure of Ukraine ДК 014-97), code of the type of economic activity (according to State Classifier of Ukraine ДК 009:2010), the average number of employees, the net value of Property, Plant and Equipment (PP&E), values of current, fixed and total assets, revenue, and cost of goods sold (COGS). All monetary variables were deflated to the level of 2013 using the Industrial Producer Price Index estimated by the State Statistics Service of Ukraine. In addition, three financial ratios were calculated: revenue by employees, revenue by total assets, and total assets by employees.

The data cleaning began with the removal of incomplete observations and observations associated with firms located in the occupied area of Donbas and in the Autonomous Republic of Crimea in 2014-2018, because Ukrainian state authorities do not exercise control there, therefore reports may be not reliable. The list of settlements where the state authorities temporarily do not exercise their powers was taken from the Order of Cabinet of Ministers of Ukraine of 7 November 2014 №1085-р, and each firm located in such settlement was dropped from the initial dataset using the first five digits of the territory code.

A number of criteria were used to detect the errors in observations. The first one was to identify the observations containing non-positive values of current, fixed, and total assets, net PP&E, or employees, each of which is hardly the feature of an operating firm. Even though a firm can operate with fully depreciated assets, removing such observations would satisfy the Cobb-Douglas production function assumption that each factor is essential. The second criterion was non-positive revenues, which we interpreted as firm exits, as well as non-positive COGS as a result of non-positive revenues.

Still, exploration of a few individual observations suggested that there are upper and lower outliers, which we suspect to be a result of the low quality of reporting, typos, or some unknown reasons. Therefore, as a next step, observations belonging to upper and lower percentiles were identified for PP&E and Employment as well as for three financial ratios: total assets per employee, revenue an by employee, and revenue by total assets. Firms associated with observations satisfying the mentioned criteria were simultaneously detected and excluded from the dataset and in all years to avoid creating additional gaps in the panel, which could be wrongly interpreted as exits, and to avoid firms, which made reporting mistakes in one year because they potentially could repeat them in a different year.

We understand that revenue by employee and revenue by total assets contain a production function dependent variable inside and excluding outliers on this basis can lead to biased estimates, but we believe that the excluded observations are mostly mistakes, and leaving them in the sample would result in even larger bias.

The descriptive statistics of the chosen variables from the cleaned dataset containing 562,602 observations is shown in Table 1. All variables are right-slewed, and some values are still questionable. For example, 25% of observations have yearly revenues of at most 6,000 UAH (nearly twice less than the minimum yearly salary in the base year); 25% of observations have at most 5 workers (while the reports of individual entrepreneurs, who are allowed to hire up to 10 workers and pay lower taxes, are not the part of the dataset); 25% of observations have a net PP&E of less than 300 UAH (equivalent to about $38 in the base year). This probably occurred due to underreporting, assets renting, and hiring the staff on a consulting basis to optimize the tax burden. However, such represents the business practice in Ukraine, therefore we did not proceed with additional data cleaning steps.

Table 1. Descriptive statistics of financial data after cleaning

Variable	Mean	SD	Min	p25	p50	p75	Max
Revenue, k UAH	94.3	309.7	0.0	6.0	20.1	68.5	18,402.7
Net PP&E, k UAH	17.0	50.6	0.0	0.3	1.9	10.1	814.7
Employees	27.4	47.8	2.0	5.0	11.0	27.0	484.0
Revenue by Employees, k UAH	619.3	1,055.5	7.0	103.4	257.0	664.0	12,258.3
Revenue by Total Assets, k UAH	2.6	3.0	0.0	0.8	1.6	3.3	29.4
Total Assets by Employees, k UAH	475.7	895.1	3.0	65.6	183.4	493.8	13,568.3

The number of observations associated with firms located in Donbas is 16,739 (3% of the cleaned dataset). Figure 1 (plotted using Power BI) shows that before the conflict started, firms were mostly concentrated in three large cities (Donetsk, Luhansk and Mariupol), but only one of them (Mariupol) was not occupied.

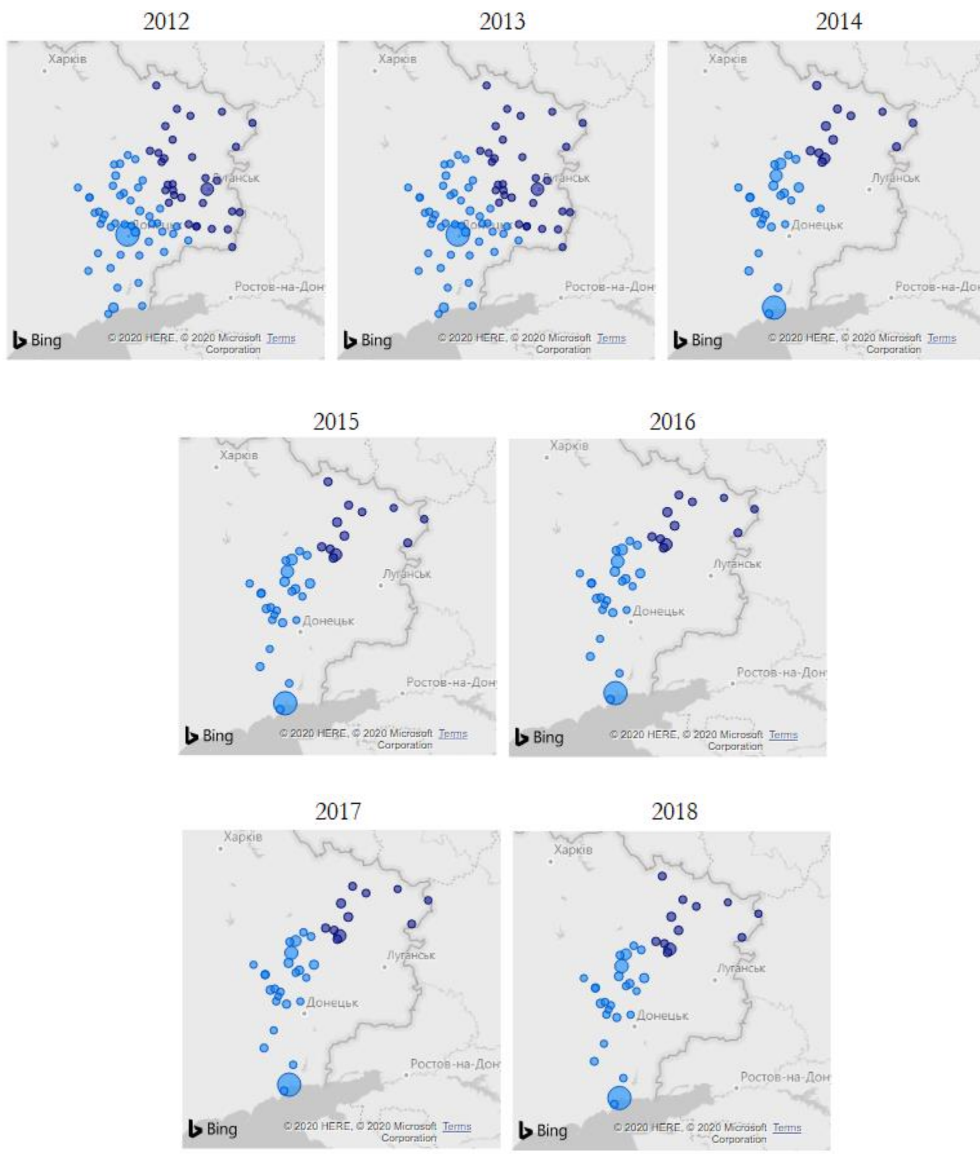

Figure 1. Location of firms in Donbas

4.2. Violence

The second part of the dataset contains the information on shelling in Donbas including date, geographical coordinates of shelling points, and corresponding territory codes. 16,922 cases of shelling were recorded in 416 settlements over the period from 2014 to 2018. The yearly number of attacks fluctuated between 2,526 and 4,243 (Table 2), about 79% of them occurred in the Donetsk region. Only 15 settlements experienced 50% of the total number of attacks over the whole period, and 11 of them being from the Donetsk region (Table 3).

Table 2. Cases of shelling by year and region

Year	2014	2015	2016	2017	2018
Donetsk region	1,645	1,794	2,656	2,943	3,141
Luhansk region	1,160	732	759	1,300	792
Total	2,805	2,526	3,415	4,243	3,933

Table 3. Distribution of cases of shelling by settlements

Cases of shelling	1-20	21-50	51-250	251-500	501-1006
Settlements in Donetsk region	199	22	21	11	6
Settlements in Luhansk region	125	14	13	2	2
Total	224	36	34	13	8

Shelling points are highly dispersed in the first year of the conflict when the invasion started, but starting from 2015 the frontline in the form of a semi-circle formed as can be seen in Figure 2 (plotted using Power BI). Further data analysis showed that attacks are equally distributed across days of the month; one third of all cases of shelling occurred in summers, a quarter in autumns, and one fifth in both winters and springs; the lowest proportion of attacks occurred in Januaries.

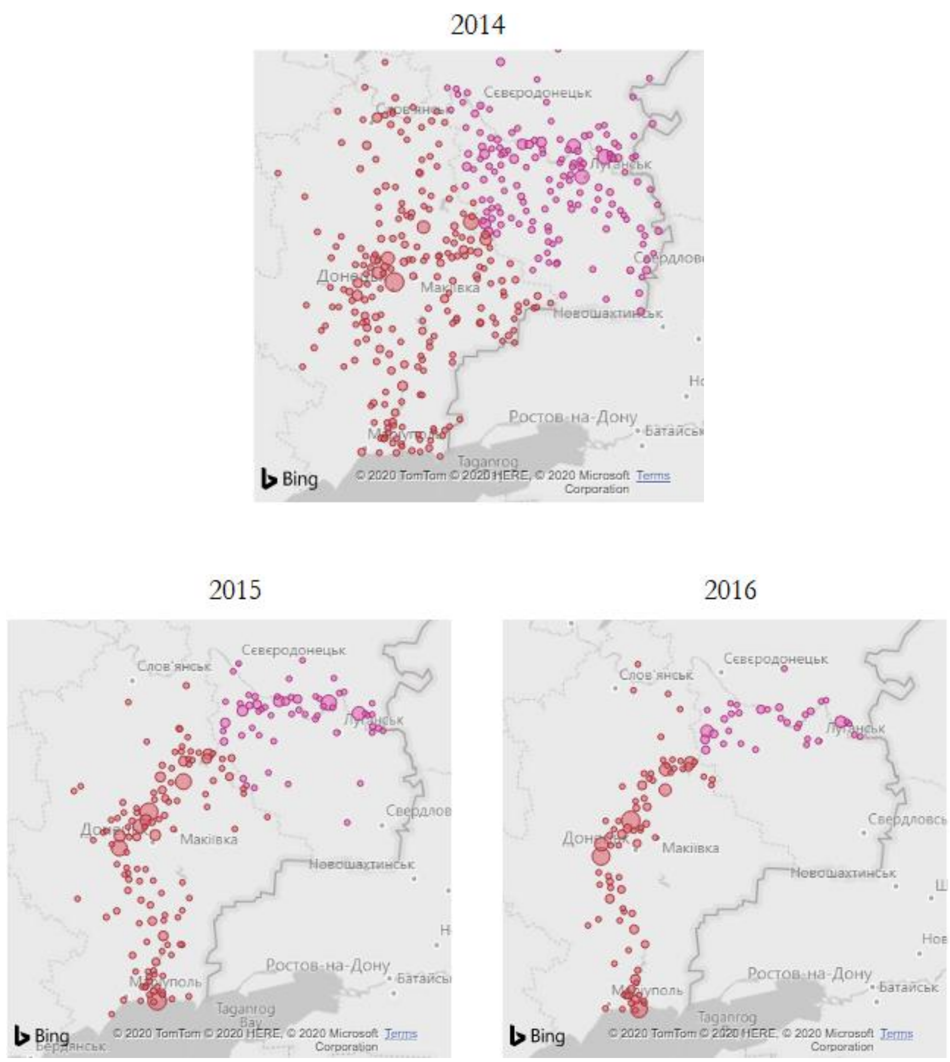

Figure 2. Location of shelling points in Donbas

2017 2018

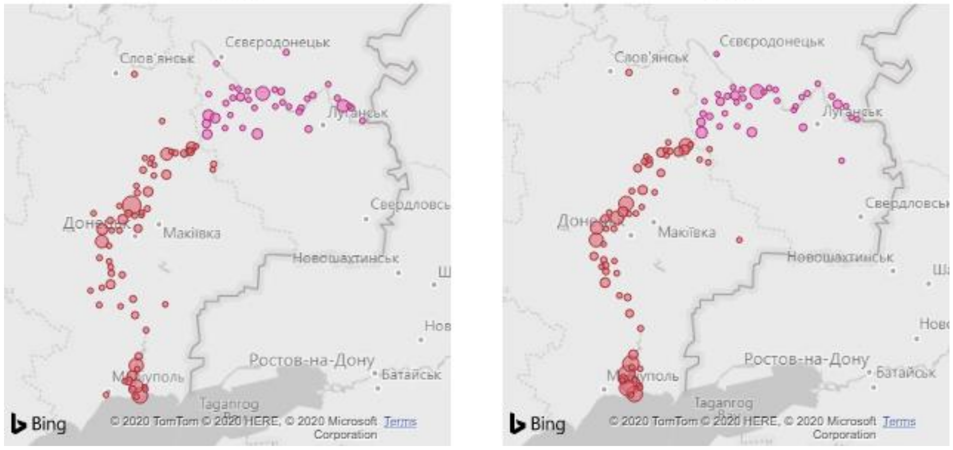

Figure 2 — Continued

C h a p t e r 5

ESTIMATES

5.1. Measures of violence

The frequency of shelling in each year was taken from the dataset directly, and the distance between each firm and each shelling point was calculated from the geographical coordinates of both firms and points of shelling. Since the longitudes and latitudes of firms are not available in the dataset, we came up with an idea to merge the list of firms with the list of shelling points by the first five digits of the territory code, which enabled to assign geographical coordinates of shelling points to each firm in Donbas region, whose location suffered at least one shelling. The coordinates of the remaining firms, whose area codes did not match the ones of any point of shelling, were assigned manually.

The decision to use five digits of the territory code works perfectly for cities of the regional subordination since they are unique for each of them, but for other municipalities five digits represent an area, which may lead to measurement errors of up to 20 kilometers. Another limitation is that the firms located in neighboring regions to Donbas area could not be assigned with coordinates given the available data, therefore analysis will be restricted to Donetsk and Luhansk regions and not account for other eastern regions of Ukraine, even though some municipalities in the neighboring regions are located closer to points of shelling than some others located in the remote corners of Donbas.

Three measures of violence were estimated with several parameters: index of violence (1), frequency of shelling in the area around the firm (2), and the average distance from the firm to the points of shelling (4). The index of violence was estimated with the degrees of denominators of 1 and 2 in each component fraction. If the coordinates of shelling coincided with the firm's location, the distance to shelling point of 1 km was assumed to avoid undefined values of index components. The frequency of shelling was estimated with three options of area limitations of 100 km, 50 km, and 25 km, meaning that points located outside the areas did not contribute to the value of the variable. The descriptive statistics of selected violence measures is shown in Table 4.

Table 4. Descriptive statistics of measures of violence

Year	Obs	Mean	SD	Min	p25	p50	p75	Max
Index (m = 1)	9,993	51.8	45.1	13.9	31.6	46.2	61.0	455.6
Index (m = 2)	9,993	12.4	71.3	0.1	0.5	1.2	2.5	733.4
AvDis	9,993	113.9	28.8	63.4	92.2	102.1	136.3	197.7
Fre (100km)	9,910	1,543.6	703.2	1.0	1,184.0	1,567.0	1,997.0	3,801.0
Fre (50 km)	8,953	491.9	483.4	1.0	102.0	316.0	836.0	1,957.0

The distribution of estimated index of violence is right-skewed for both m = 1 and m = 2, however, the dispersion of the version with m = 2 is notably higher with values mostly concentrated in close to the origin (Appendix A) despite that the correlation between indexes is about 92% (Table 5). The estimated average distance from firms to points of shelling follows a bimodal distribution with the highest frequencies of about 90 and 140 km. On average, a firm in Donbas witnessed about 1,500 cases of shelling in the radius of 100km and about 500 cases of them in the area of 50 km. Also, important to note that correlation between average distance and frequency of shelling in the 100km area is about -66%, which will contribute to high variance of the coefficients in the model, so using a frequency in 50km (-24% correlation) will be preferred. Finally, the average number of workers as a proxy for the firm size does not correlate with measures of violence, therefore it is an appropriate control variable for regressions.

Table 5. Correlation matrix between measures of violence and firm size

Variable	Index (m = 1)	Index (m = 2)	AvDis	Fre (100 km)	Fre (50 km)	Workers
Index (m = 1)	1.00					
Index (m = 2)	0.92	1.00				
AvDis	-0.16	-0.11	1.00			
Fre (100 km)	0.22	-0.01	-0.66	1.00		
Fre (50 km)	0.35	0.04	-0.24	0.56	1.00	
Workers	0.00	0.00	-0.06	0.02	0.00	1.00

5.2. Production function and TFP

The production function was estimated using a two-step system GMM approach (Appendix B) separately for each industry over the period from 2012 to 2018 using the data for firms in all regions of Ukraine. TFP was estimated for each firm as a sum of intercept and residual from the production function, where PP&E was taken as capital and the average number of employees as labor. Both factors of production were assumed to be endogenous and thus their first lags, as well as the first lag of output, were instrumented in GMM style, while year dummies were used as instrumental variables in levels equation.

18 industries were differentiated according the code of the type of economic activity, which is used in Ukraine to classify what business activities a company is engaged in. It would be desirable to differentiate industries using a lower level of classification, which accounts for over 80 industries, but this would result in a small number of observations in each industry, which decreases the efficiency of a GMM estimator.

The estimates in Appendix B show that for all industries the null hypothesis of AR(1) process according to Arellano–Bond test was failed to be rejected, as expected by the specification. Also, for all industries the null hypothesis of AR(2) process was rejected at 1% level of significance, but 2 out of 18 industries failed this test at 5% level of significance.

The dynamics of estimated average TFP across industries over years is plotted in Appendix C. Top industries in terms of average TFP in Ukraine are real estate, finance and insurance, wholesale and retail trade, agriculture, the supply of electricity and gas, IT and professional services. The ones with lowest average TFP are education and healthcare. An interesting fact is that industries with higher average TFP experienced higher volatility in 2012-2018 (exclusion is a processing industry, which faced a sharp increase in 2014). On average across all firms, TFP was increasing until 2014 and after that fluctuated with a sidewise trend, but the trend is different across all industries. What clearly makes firms in Donbas different form all regions regarding the average TFP trend is of Ukraine is the mining and quarrying industry, which has one of the highest TFP in the region. The average productivity across all firms in Donbas in the unoccupied area fluctuated over 2012-2018.

5.3. Regression analysis

The fixed effect estimates of models (5) and (6) are shown in Table 6, where the dependent variable is the TFP in logarithm form and coefficients of all variables other than measures of violence is hidden. The signs of coefficients on measures of violence in all regressions are consistent with the intuition that distancing from violence is associated with better performance, while the higher intensity of violence in the nearby area is associated with weaker performance. Also, firm size approximated with the logarithm of the average yearly employees is significant at 0.001 level in all regressions, most year dummies are significant and most industry dummies are statistically insignificant at 0.05 level.

In FE1, the negative and statistically significant coefficient of the index supports our hypothesis that war has a significant negative effect on TFP, which increases in the intensity of violence and decreases in distance to the shelling points. A hundred points increase in the index is associated with a 0.13% decrease in TFP under the fixed controls and individual firm effect. The model (6) in its full specification has only one measure of violence significant, which is the average distance to shelling under frequency area restriction of 100 km (FE2), but neither of measures is significant when the area is restricted to 50 km (not reported).

However, when average distance and frequency are included separately, their coefficients gain more explanatory power. In FE3 the coefficient on distance becomes higher and significant at 0.01, suggesting that ceteris paribus an increase of average distance to the point of shelling of 100 km is associated with a 0.34% increase in TFF. Also, frequencies for both 100km and 50km are significant at 0.001 in FE4 and FE5, and the coefficient is slightly higher in absolute value under the assumption that points located further than 50km have no effect. The interpretation is that ceteris paribus 1000 additional attacks in the 100km zone around the firm are associated with a drop in TFP of 0.14-0.18%.

Table 6. Estmates of models (5) and (6)

	FE1	FE2	FE3	FE4	FE5
Index	-1.3e-03*** (1.8e-04)				
AvDis		2.6e-03* (1.3e-03)	3.4e-03** (1.3e-03)		
Fre (100 km)		-4.6e-05 (2.7e-05)		-1.4e-0.4*** (1.2e-05)	
Fre (50 km)					-1.8e-04*** (2.0e-05)
…					
R2	0.16	0.22	0.22	0.17	0.18
N	13,676	9,910	9,993	13,593	12,636

*** p<0.001, ** p<0.01, * p<0.05, p < 0.1

Next, we run models (7) and (8) using a fixed effect estimator. The coefficients on measures of violence in the estimated model (8) turned out to be statistically insignificant, so only estimates of (7) and of incomplete specifications of (8) are reported in Table 7.

Regression FE6 shows that coefficient on the index is negative and significant at 0.001 level, suggesting a negative effect of violence on TFP in 2014, which is the base year in the regression (neither 2012 nor 2013 is a base year, since their interactions with index are zeros, thus omitted in the model). Combined with a 0.05 level significant positive intersection between index and year 2015 dummy, which is lower in absolute value than coefficient on the index, this leads us to the conclusion that the effect of violence on TFP decreased but remained significant in 2015.

The interactions between index and dummies for other years are not statistically different from zero, which is interpreted as the maintenance of the negative effect of violence on TFP in 2016-2017 at the level of the base year. However, there is also evidence that the effect of violence intensified in 2018, the coefficient on the 2018 year dummy is negative and 2 times higher than that in the base year. So, we observed the following evolution: an additional increase of 100 points in the index is ceteris paribus associated with the decrease in TFP of 0.11% in 2014, 0.04% in 2015, 0.11% in 2016-2017, and 0.33% in 2018.

Regressions FE7 and FE8 also show significant coefficients in the base year with intuitive signs, but the interactions between average distance to shelling and frequency of shelling in the area are all insignificant, meaning that the effect of violence did not change in 2015-2018. Finally, according to F9, the frequency of shelling in the area of 50 km does not influence TFP in 2017 and 2018 as much as in the base year. It is interpreted that the effect of additional 1000 cases of shelling in the area of 50 km was ceteris paribus associated with a decrease in TFP of 2.2% in 2014-2016, but softened to 0.1% in 2017 and 0.5% in 2018.

Table 7. Estimates of model (7) and incomplete specifications of model (8)

	FE6	FE7	FE8	FE9
Index (m = 1)	-1.1e-03***			
	(2.9e-04)			
AvDis		3.6e-03**		
		(1.3e-03)		
Fre (100 km)			-8.0e-05***	
			(1.6e-05)	
Fre (50 km)				-2.2e-04***
				(4.8e-05)
…*Year2015	7.4e-04*	2.7e-04	-4.0e-05	8.4e-05
	(3.3e-04)	(6.6e-04)	(3.6e-05)	(7.0e-05)
…*Year2016	-2.8e-03	1.2e-04	-1.5e-05	1.1e-04
	(1.7e-03)	(7.4e-04)	(3.6e-05)	(6.2e-05)
…*Year2017	-1.5e-03	-7.3e-04	4.0e-05	2.1e-04***
	(9.7e-04)	(7.3e-04)	(2.7e-05)	(5.4e-05)
…*Year2018	-2.3e-03**	1.4e-04	-5.1e-05	1.7e-04**
	(8.4e-04)	(7.9e-04)	(2.8e-05)	(5.5e-05)
…				
r2	0.17	0.22	0.18	0.19
N	13,676	9,993	13,593	12,636

*** p<0.001, ** p<0.01, * p<0.05, p < 0.1

Chapter 6

CONCLUSIONS

We managed to find statistical evidence for the negative effect of violence on the productivity of Ukrainian firms, which is contributed by both proximity and intensity of the violence in Donbas. This was shown with the help of regression models under different specifications, where a dependent variable, TFP, is explained by one of two common measures of violence, distance and intensity, while industry, size, and individual particularities of firms are controlled for.

Also, we designed the index of violence, which is increasing in intensity and decreasing in distance. The index has favorable features to measure violence. It has an advantage over other measures in cases when, firstly, distance and frequency are correlated and could not be accounted for simultaneously, and secondly, when it is possible to assume that both distance and intensity have an effect, which consists of separate effects of each point of violence.

However, the estimated effect of violence on TFP is quite small compared to industry fluctuations in TFP from year to year. For example, a maximum value of the index in the dataset is 455, which corresponds to about 0.5% decrease in TFP in 2014 given the coefficient on the index of -0.001.

Finally, the evolution of the negative effect of violence on TFP was observed, which did not let us support the result of Voronin (2016), who found that the negative effect of war on productivity disappeared in 2016. Also, we did not find clear evidence on firm adaptation to the conflict.

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APPENDIX A

DISTRIBUTIONS OF ESTIMATED MEASURES OF VIOLENCE

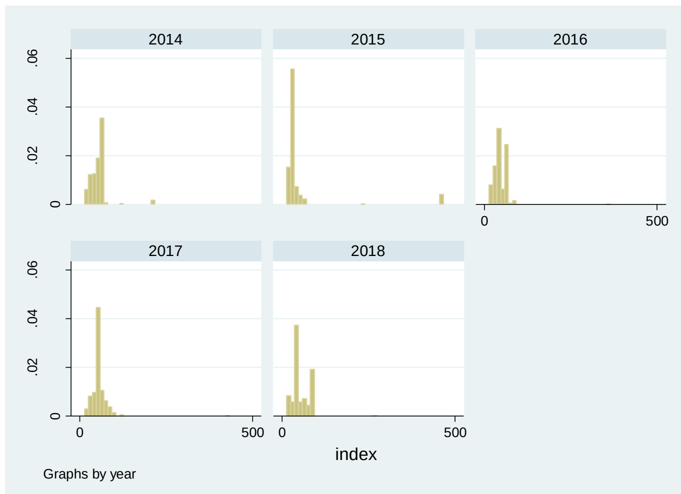

Figure 3. Distributions of index of violence (m = 1)

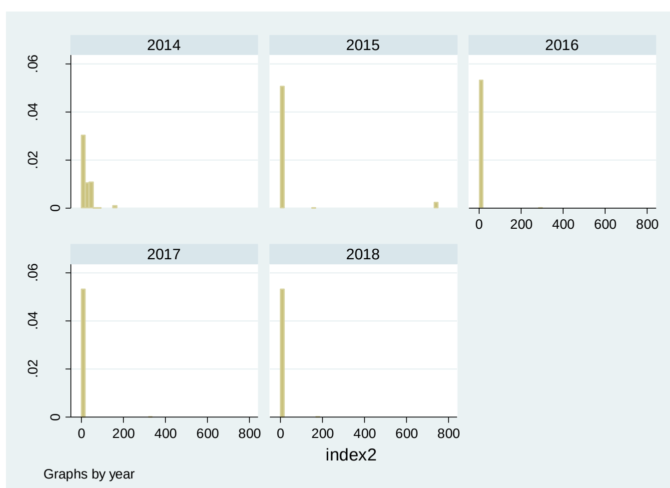

Figure 4. Distributions of index of violence (m = 2)

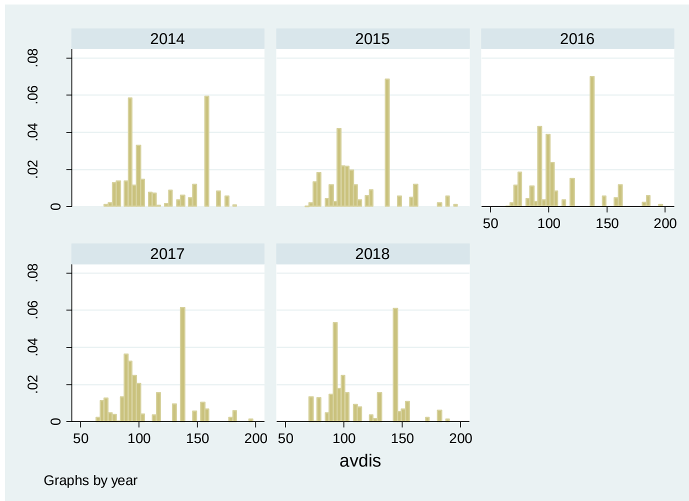

Figure 5. Distribution of average distance to points of shelling

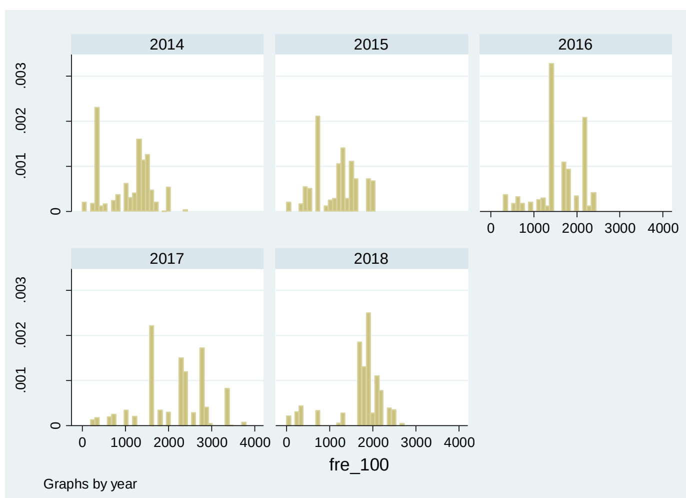

Figure 6. Distribution of frequency of shelling in the area (100 km)

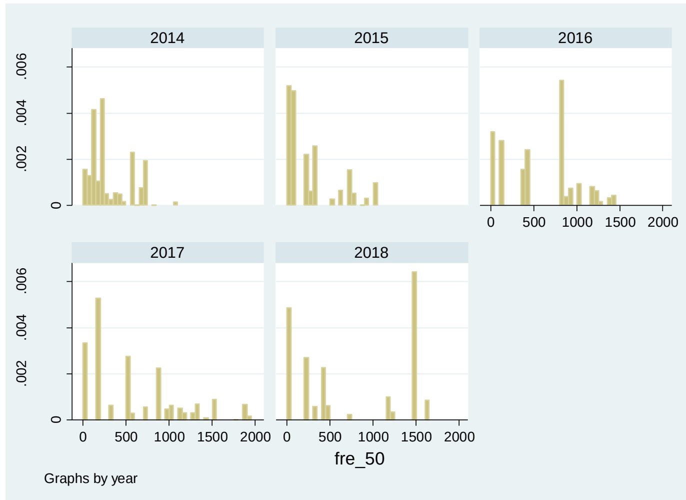

Figure 7. Distributions of the frequency of shelling in the area (50 km)

APPENDIX B

PRODUCTION FUNCLTON ESTIMATES

Table 8. Arellano-Bond test for AR in first difference

№	Industry	Arellano-Bond test for AR in first differences	
		AR(1) Pr > z	AR(2) Pr > z
1	Activities in the field of administrative and support services	0.00	0.03
2	Agriculture, forestry and fisheries	0.00	0.31
3	Arts, sports, entertainment and recreation	0.00	0.92
4	Construction	0.00	0.96
5	Education	0.00	0.35
6	Finance and insurance	0.00	0.94
7	Health care and social assistance	0.00	0.03
8	Information and telecom	0.00	0.60
9	Mining and quarrying	0.00	0.64
10	Processing industry	0.00	0.70
11	Professional, scientific and technical activities	0.00	0.75
12	Provision of other types of services	0.00	0.64
13	Real estate transactions	0.00	0.57
14	Supply of electricity, gas, steam and a	0.00	0.58
15	Temporary accommodation and catering	0.00	0.08
16	Transport, warehousing, postal and courier activities	0.00	0.02
17	Water supply; sewerage, waste management	0.00	0.75
18	Wholesale and retail trade; repair of motor vehicles and motorcycles	0.00	0.00

Table 9. Production function estimates

	GMM1	GMM2	GMM3	GMM4	GMM5	GMM6
yr2013	0.067***	-0.013	0.124***	0.073***	0.073*	-0.001
	(0.020)	(0.009)	(0.036)	(0.016)	(0.029)	(0.040)
yr2014	-0.106***	0.270***	-0.151**	-0.008	-0.132***	-0.081
	(0.029)	(0.015)	(0.051)	(0.024)	(0.037)	(0.045)
yr2015	-0.051	0.447***	-0.106	0.155***	-0.160***	-0.215***
	(0.027)	(0.011)	(0.057)	(0.021)	(0.036)	(0.052)
yr2016	-0.214***	0.276***	-0.243***	-0.005	-0.344***	-0.256***
	(0.031)	(0.010)	(0.059)	(0.025)	(0.041)	(0.053)
yr2017	-0.071*	0.159***	-0.143*	0.092***	-0.261***	-0.244***
	(0.030)	(0.010)	(0.064)	(0.020)	(0.042)	(0.054)
yr2018	-0.035	0.213***	-0.164**	0.096***	-0.211***	-0.291***
	(0.031)	(0.011)	(0.064)	(0.021)	(0.046)	(0.062)
ln(K)	0.170*	1.169***	0.108*	0.330***	0.237***	0.273***
	(0.074)	(0.045)	(0.048)	(0.070)	(0.051)	(0.045)
L.ln(K)	-0.058	-0.769***	-0.086	-0.189**	-0.204***	-0.127**
	(0.069)	(0.042)	(0.045)	(0.059)	(0.055)	(0.041)
ln(L)	1.722***	0.428***	1.622***	2.279***	1.494***	1.134***
	(0.130)	(0.089)	(0.107)	(0.109)	(0.102)	(0.111)
L.ln(L)	-0.814***	-0.066	-0.732***	-1.059***	-0.271**	-0.466***
	(0.124)	(0.072)	(0.119)	(0.081)	(0.088)	(0.103)
_cons	0.105	1.314***	-0.068	-0.116	-1.126***	1.134***
	(0.150)	(0.069)	(0.221)	(0.122)	(0.186)	(0.184)
N	13,165	70,070	1,514	40,000	2,507	1,199

*** p<0.001, ** p<0.01, * p<0.05, p < 0.1

Table 9 — Continued

	GMM7	GMM8	GMM9	GMM10	GMM11	GMM12
yr2013	0.023	0.024	0.240***	0.134***	0.044*	0.051
	(0.026)	(0.019)	(0.043)	(0.011)	(0.020)	(0.035)
yr2014	-0.132***	0.013	0.236***	0.086***	-0.023	-0.096*
	(0.036)	(0.034)	(0.055)	(0.021)	(0.037)	(0.043)
yr2015	-0.156***	-0.004	0.294***	0.225***	-0.008	-0.099*
	(0.033)	(0.029)	(0.056)	(0.016)	(0.030)	(0.045)
yr2016	-0.333***	-0.079*	0.190**	0.014	-0.171***	-0.328***
	(0.040)	(0.037)	(0.061)	(0.020)	(0.034)	(0.052)
yr2017	-0.225***	-0.072*	0.251***	0.013	-0.142***	-0.199***
	(0.039)	(0.033)	(0.056)	(0.015)	(0.026)	(0.051)
yr2018	-0.212***	-0.026	0.286***	0.050**	-0.128***	-0.152**
	(0.040)	(0.036)	(0.057)	(0.015)	(0.029)	(0.058)
ln(K)	0.107	0.618***	0.473***	0.235***	0.628***	0.307**
	(0.073)	(0.089)	(0.078)	(0.070)	(0.099)	(0.096)
L.ln(K)	-0.051	-0.389***	-0.321***	-0.135*	-0.474***	-0.243**
	(0.063)	(0.079)	(0.080)	(0.063)	(0.088)	(0.090)
ln(L)	2.044***	1.404***	1.912***	2.838***	2.084***	2.139***
	(0.174)	(0.170)	(0.128)	(0.114)	(0.184)	(0.256)
L.ln(L)	-0.913***	-0.644***	-1.012***	-1.744***	-1.165***	-1.367***
	(0.147)	(0.153)	(0.132)	(0.095)	(0.145)	(0.252)
_cons	-0.947***	0.815***	0.077	-0.049	0.438**	0.144
	(0.186)	(0.178)	(0.266)	(0.097)	(0.161)	(0.282)
N	6,914	17,417	2,036	82,424	24,704	4,360

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, $p < 0.1$

Table 9 — Continued

	GMM13	GMM14	GMM15	GMM16	GMM17	GMM18
yr2013	0.061**	0.018	0.080***	0.094***	0.080***	0.103***
	(0.020)	(0.024)	(0.018)	(0.022)	(0.017)	(0.011)
yr2014	0.186***	-0.187***	-0.025	0.046	-0.091***	0.016
	(0.045)	(0.030)	(0.037)	(0.033)	(0.027)	(0.020)
yr2015	0.107**	-0.080*	-0.003	0.119***	-0.128***	0.117***
	(0.038)	(0.032)	(0.035)	(0.032)	(0.024)	(0.016)
yr2016	0.142**	-0.111**	-0.140***	-0.059	-0.312***	-0.097***
	(0.049)	(0.039)	(0.042)	(0.036)	(0.029)	(0.020)
yr2017	0.056	-0.100*	-0.085*	0.022	-0.239***	-0.080***
	(0.034)	(0.040)	(0.035)	(0.029)	(0.025)	(0.014)
yr2018	0.060	-0.051	-0.053	0.040	-0.189***	-0.072***
	(0.036)	(0.045)	(0.037)	(0.031)	(0.026)	(0.016)
ln(K)	1.269***	0.278***	0.205*	0.178*	0.195**	0.180**
	(0.128)	(0.057)	(0.092)	(0.082)	(0.067)	(0.063)
L.ln(K)	-1.029***	-0.122*	-0.166	-0.128	-0.214**	-0.101
	(0.127)	(0.051)	(0.087)	(0.072)	(0.067)	(0.054)
ln(L)	1.322***	1.194***	2.035***	2.764***	1.635***	3.328***
	(0.171)	(0.135)	(0.117)	(0.158)	`	(0.113)
L.ln(L)	-0.773***	-0.490***	-0.941***	-1.609***	-0.694***	-1.882***
	(0.136)	(0.109)	(0.108)	(0.135)	(0.135)	(0.093)
_cons	0.485***	0.990***	-0.645***	-0.102	-0.374*	0.252**
	(0.128)	(0.244)	(0.106)	(0.158)	(0.157)	(0.086)
N	28,760	3,033	13,560	22,683	9,403	124,191

*** $p<0.001$, ** $p<0.01$, * $p<0.05$, $p < 0.1$

APPENDIX C

FIRM PRODUCTIVITY TRENDS ACROSS INDUSTRIES

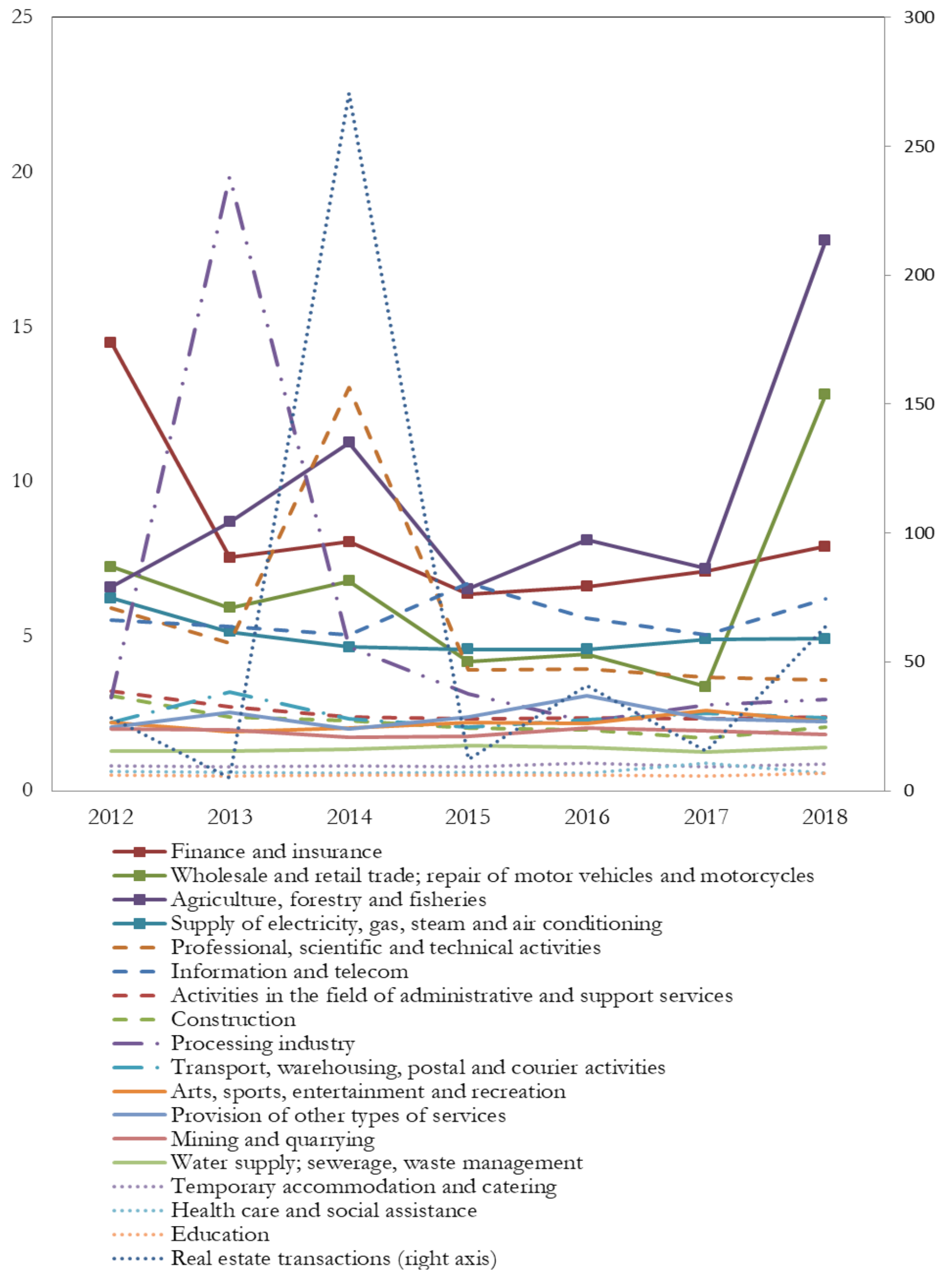

Figure 8. Dynamics of average TFP by industries in all regions

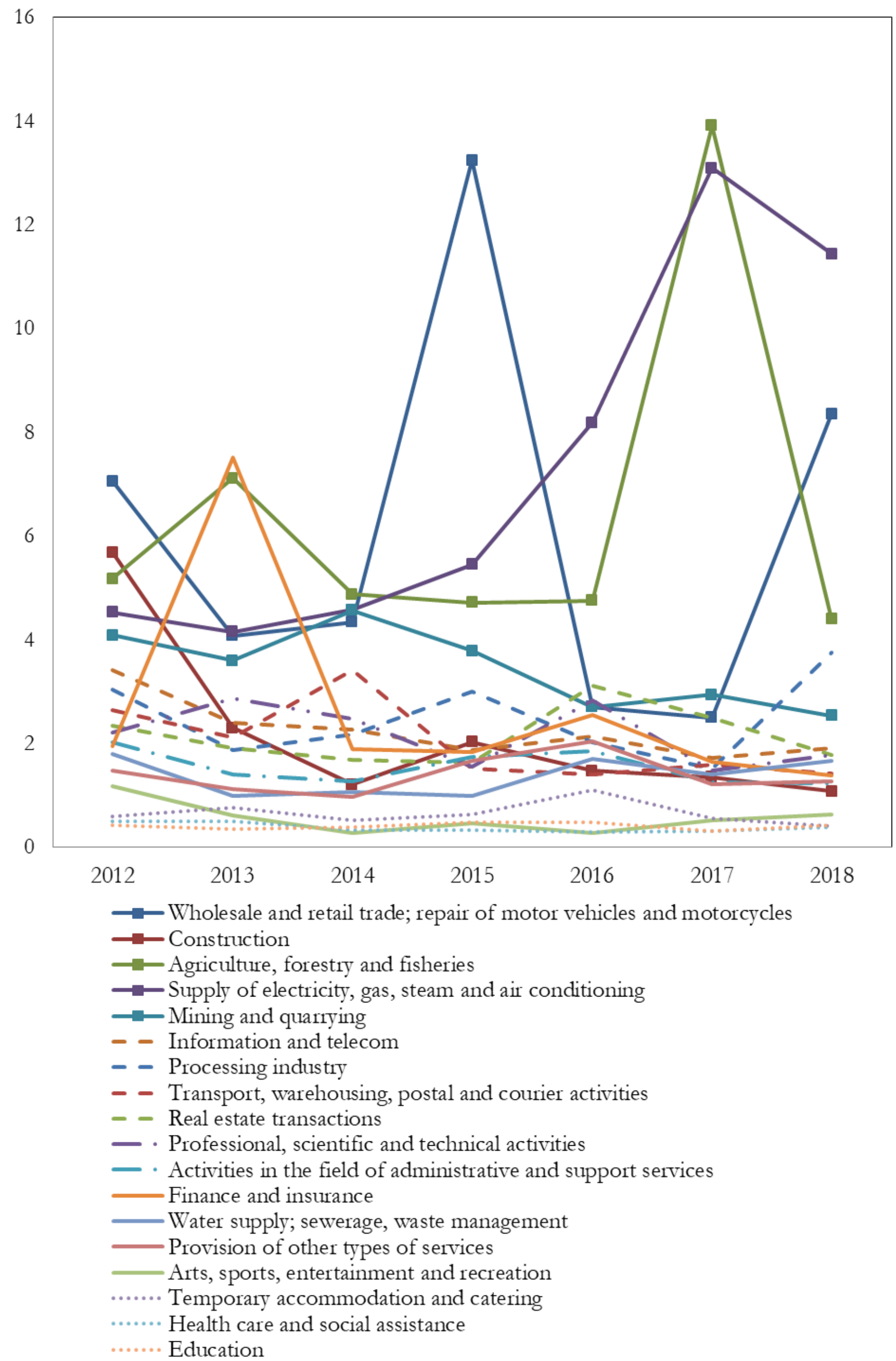

Figure 9. Dynamics of average TFP by industries in Donbas