TONY BLAIR INSTITUTE FOR GLOBAL CHANGE

From Economic Recovery to Global Food Security: The Urgent Need to Demine Ukraine

Methodology Note

1. INTRODUCTION

Ukraine is currently considered to be the country which is most heavily impacted by landmines and explosive remnants of war (ERW) in the world.[1] An estimated 139,300 square kilometres of land – one-quarter of the country – is in need of survey. To better understand the ramifications of this issue for Ukraine's development, the Tony Blair Institute for Global Change (TBI) has conducted an economic-impact assessment (EIA) of landmines and ERW in the country. Crucially, this study sheds light on the impact of landmines and ERW on economic outcomes using a natural quasi-experimental setting, evidencing why demining is crucial for Ukraine's economic recovery and development. As such, the EIA could significantly bolster efforts to attract additional funding for demining, as well as innovate with new sources of public and private financing.

This methodology note details the processes by which the EIA was carried out. In summary, Section Two outlines the theoretical foundations of our approach, Section Three summarises the data that were used, Section Four explains how regional GDP was estimated, Section Five details the final models that were developed and Section Six provides a deeper analysis into the details of the methodology.

[1] Ministry of Economy, government of Ukraine

2. THEORETICAL MODEL

The goal of our study has been to estimate the impact of landmines and ERW on a set of key economic outcomes – GDP, exports and tax revenues – at the regional (oblast) level.

We investigate the impact of both the suspected and confirmed presence of landmines and ERW on the economic outcomes of interest, as both are likely to suppress economic activity in affected oblasts. However, we estimate the impacts of suspected and confirmed landmines and ERW separately, given probable differences in the ways that both influence the economy. As such, our analysis has two independent variables of interest: the share (per cent) of suspected hazardous area (SHA) in a given oblast and the share (per cent) of confirmed hazardous area (CHA).

Taking into account the objectives of the study, the manner in which the presence of unexploded ordnance is distributed geographically and limitations on available data, we selected a difference-in-differences regression approach. A regression is a statistical method aimed at capturing the correlation between variables present in the data.

The regression used in our analysis can be summarised in the following formula, which is calculated separately for each outcome and for CHA and SHA land:

$$Y_{region} = \alpha + Shr_{region}\beta_1 + Post_t\beta_2 + Shr_{region} * Post_t\delta + X'_{region,t} + \varepsilon \quad (1)$$

Where:

- Y_{region}: GDP, exports or taxes in a given oblast
- Shr_{region}: Share (percentage) of SHA or CHA land in a given oblast
- $Post_t$: Time variable for the post-full-scale invasion period
- $X'_{region,t}$: Controls – other variables which could also impact the economic outcomes of interest, including war intensity, direct destruction and damages, number of victims and injured people as a result of landmines and ERW, and chemical contamination

For clarity, the regression in formula (1) is equivalent to performing the calculation:

$$Effect\_of\_mines = \left[GDP_{region\_treated,post-war} - GDP_{region\_treated,pre-war}\right] - \left[GDP_{region\_not\_treated,post-war} - GDP_{region\_non\_treated,pre-war}\right] \quad (2)$$

with the crucial addition that we also control for the impact of other variables which could affect the economic outcomes of interest. The regions included in the “treated” group are the oblasts which include some portion of SHA or CHA land; in other words, the oblasts which have been impacted by landmines during Russia’s full-scale invasion of Ukraine (Chernihiv, Dnipropetrovsk, Donetsk, Kharkiv, Kherson, Kyiv, Mykolaiv, Sumy, Zaporizhzhia and Zhytomyr). This is with the exception of Luhansk, for which insufficient data were available. The regions included in the “non-treated” group are all other oblasts in Ukraine.

The coefficient δ captures the impact of suspected or confirmed presence of landmines and ERW on each economic outcome in a given oblast, when all other variables are held constant. In essence, δ represents the impact of one additional percentage point of SHA/CHA land on each outcome. As such, to estimate the total impact of suspected or confirmed unexploded ordnance on the economic outcomes of interest, we multiply, for each oblast, the coefficient δ by the share of SHA or CHA land in the oblast.

Addendum: Simplified Explanation of the Process

To simplify, the whole process can be summarised as follows. We start from the data (for example, from Y_{region}, $Shr(mines)_{region}$, $Post_t$, $X'_{region,t}$) and we use the regression to estimate the unknown coefficients (in particular δ, for example, our coefficient of interest). We therefore obtain an estimate $\hat{\delta}$, which is a number capturing the average treatment effect (ATE) of one unit more of CHA or SHA on our outcome of interest, holding the controls fixed. Once we have estimated this coefficient, we then multiply it by the share of CHA or SHA for every region and obtain the impact on the economic outcome of interest.

3. DATA DESCRIPTION

This section briefly describes the data used in the analysis. The data sets span 27 Ukrainian oblasts, covering data at the monthly level (or yearly, depending on the variable) from January 2018 to November 2023.

Data sets include:

- Share of land in each oblast under CHA/SHA after the beginning of the full-scale invasion
- Regional GDP per year until 2021; national GDP per year after the beginning of the full-scale invasion
- Regional exports per year and month for all years available after 2018
- Regional tax revenues per year and month for all years available after 2018
- War intensity after the beginning of the full-scale invasion (both in aggregated and disaggregated form)
- Direct destruction and damages by oblast and year after the beginning of the full-scale invasion
- Chemical contamination by oblast and year after the beginning of the full-scale invasion
- Number of injured and killed people by oblast and year after the beginning of the full-scale invasion

4. GDP ESTIMATION

Regional GDP data for time periods after the full-scale invasion are not available. As such, we developed a methodology to estimate these missing data: we adjusted the last GDP available at regional level (2021) by the national change in GDP due to the war and the average between the percentage decrease in export and taxes. We performed this exercise for years 2022 and 2023.

$$GDP\ Estimated_{region,year} = GDP_{region,2021} * \left(1 - National\ \%\ chng\ in\ GDP_{year-2021}\right) * \left(1 - \frac{\%\ change\ in\ exp_{region,year-2021} + \%\ change\ in\ tax_{region,year-2021}}{2}\right)$$

We used two different approaches in evaluating changes in GDP at the national level:

i) nominal GDP data (source: State Statistics Service of Ukraine).

ii) real GDP data change (source: World Bank data). These data are combined with nominal data from the State Statistics Service of Ukraine, adjusting for inflation, and are used to construct yearly GDP summing the real flows obtained.

This method of estimating GDP is corroborated by a high correlation between GDP, taxes and export before the war (for the period when we have GDP data available at regional level): GDP correlates at 0.86 with tax revenues and at 0.92 with exports.

5. EMPIRICAL ANALYSIS

This section describes the analysis performed.

5.1 Data sets

The analysis relies on the following data sets:

- **CHA/SHA data set**: data set at oblast level with share of confirmed (CHA) or suspected (SHA) area containing landmines and ERW after the beginning of the full-scale invasion
- **Armed Conflict Location and Event Data (ACLED)**: data set reporting the number of conflicts between the Russian and Ukrainian armies in each oblast after the beginning of the conflict, both aggregated and disaggregated by type of conflict
- **Import/export data set**: monthly exports and imports in USD for every oblast from January 2018 to November 2023
- **Regional tax-revenues data set**: monthly regional tax in Ukrainian hryvnia (UAH) for every oblast from January 2018 to November 2023
- **GDP data set**: yearly national (January 2018 until November 2023) and regional (January 2018 until December 2021) GDP estimates
- **Direct-war-damages data set**: regional damages in the period after the full-scale invasion
- **Chemical-contamination data set**: regional chemical contamination in the period after the full-scale invasion
- **Injuries and fatalities data set**: number of individuals injured and killed per region in the period after the full-scale invasion

5.2 Data cleaning and definition of variables

The full data set consists of a panel with 27 oblasts and 71 months. The data-cleaning process included the following steps:

- Negative values for exports were replaced with zeros
- Tax revenues from the military were subtracted from total tax revenues

Key variables are defined as follows:

- **Tax revenues:** general tax revenues, originally in UAH, then converted into USD and adjusted for the inflation rate of UAH, from all sources minus military taxes
- **Exports:** USD value of regional exports
- **GDP:** GDP in UAH, see Section Four
- **SHA/CHA share:** area of the oblast potentially or actually containing landmines and ERW

- **Post:** the threshold date for the beginning of the full-scale invasion is set at 1 March 2022 (the first month after the beginning of the full-scale invasion)
- **War-intensity (ACLED) share:** the share of conflicts in every region over the total number of conflicts in Ukraine
- **Chemical-contamination share:** share of chemical contamination for the period after the full-scale invasion
- **War-damages share:** share of war damages for the period after the full-scale invasion
- **Killed and injured share:** share of injured and killed individuals for the period after the full-scale invasion

5.3 Specifications

For each output considered (GDP, taxes, exports) a different difference-in-difference model specification was implemented:

i) Taxes

The specification for the taxes consists of a regression at the year-oblast level of local taxes collected on the CHA/SHA. Taxes are originally in UAH, hence they are adjusted for inflation in Ukraine and converted into USD for ease of comparability. The following specification is adopted:

$$Taxes_{region} = \alpha + Shr(ERWs)_{region}\beta_1 + Post_t\beta_2 + Shr(ERWs)_{region} * Post_t\delta + X'_{region,t}\gamma + \varepsilon$$

With X being a vector of controls including: share of chemical contamination by region, share of war destruction by region, share of killed people by region, share of injured people by region (all interacted with the Post variable to account for time trends) and ACLED war-violence-related variables interacted by year. The regression is weighted by regional area.

ii) Exports

The specification for the exports consists of a regression at the year-oblast level of exports in USD on the CHA/SHA. The following specification is adopted:

$$Exports_{region} = \alpha + Shr(ERWs)_{region}\beta_1 + Post_t\beta_2 + Shr(ERWs)_{region} * Post_t\delta + X'_{region,t}\gamma + \varepsilon$$

With X being a vector of controls including: share of chemical contamination by region, share of war destruction by region, share of killed people by region, share of injured people by region (all interacted with the Post variable to account for time trends) and ACLED war-violence-related variables interacted by year. The regression is weighted by regional area.

iii) GDP

The specification for GDP consists of a regression at the year-oblast level of nominal GDP on the CHA/SHA. In this setting, a quadratic term for the SHA is included, on top of the canonical-saturation term, to account for non-linear effects of the SHA. The following specification is adopted:

$$GDP_{region} = \alpha + Shr(ERWs)_{region}\beta_1 + Post_t\beta_2 + Shr(ERWs)_{region} * Post_t\delta + Shr(EWRs)^2_{region} + X'_{region,t}\gamma + \varepsilon$$

With X being a vector of controls including: share of chemical contamination by region, share of war destruction by region, share of killed people by region, share of injured people

by region (all interacted with the Post variable to account for time trends) and ACLED war-violence-related variables interacted by year. The regression is weighted by regional area.

5.4 Results

The final results were obtained by performing a linear combination of the coefficients on CHA and SHA regressors. They are summarised below.

Estimates of the impact of SHA and CHA on GDP, taxes and exports (USD, millions)

	SHA (March 2022 to December 2023)	CHA (March 2022 to December 2023)	SHA + CHA (March 2022 to December 2023)	SHA + CHA (Annual)
GDP	- 16,436.21	- 4,157.32	- 20,593.53	**- 11,232.83**
Taxes	- 1,253.71	- 799.06	- 2,052.77	**- 1,119.69**
Exports	- 10,918.49	- 5,458.58	- 16,377.07	**- 8,932.95**

5.5 Robustness and sensitivity checks

The following robustness and sensitivity checks were performed:

- Change date of the shock to account for anticipation effects: no significant change in estimates
- Include taxes from military: no significant change in estimates
- Running the whole regression with standardised coefficients to check the relative magnitude of the effects of each variable
- Change regression weighting: no significant change

5.6 Export calculations

An extension of our analysis evaluated the impact of landmines and ERW on agricultural and food exports from Ukraine. This was calculated as follows:

The percentage share of export goods classified as agricultural at the oblast level was determined by adding the value of agricultural and food goods exported over three years (2019 to 2021) and dividing this value by the total value of goods exported during the same period. The percentage share was then multiplied by the annualised combined SHA and CHA impact on exports for each oblast, as estimated above. This allowed us to estimate the impact of landmines and ERW on each oblast's agricultural and food exports.

The following categories of goods were included as "agricultural and food" exports:

- live animals
- meat and edible offal
- milk and dairy products, poultry eggs, natural honey
- other products of animal origin
- vegetables, root crops
- edible fruits and nuts
- coffee, tea
- grain crops

- products of flour milling and grain industry
- seeds and fruits of oil plants
- fats and oils of animal or vegetable origin
- meat and fish products
- finished grain products
- vegetable-processing products
- different food products

6. IN-DEPTH ANALYSIS OF THE METHODOLOGY: DETAILS

6.1 Deep dive into methodology

The research question underlying this analysis is: “What is the effect of landmines and ERW on tax revenues, exports and GDP?” Framed within the experimental benchmark of Angrist and Pischke (2008), the ideal random experiment would involve the random assignment of ERW across the oblasts of Ukraine. However, such randomisation is not feasible, as ERW contamination is not exogenously determined but rather arises from conflict, making it inherently endogenous.

In order to address this challenge and recover a causal effect, we employ a difference-in-differences approach. This method mitigates some of the endogeneity concerns by comparing treated and untreated regions over time, though it does not fully eliminate the issue of non-random treatment assignment. Consequently, the results should be interpreted as providing strong correlational evidence of the impact rather than a definitive causal inference, given the constraints of achieving fully exogenous variation in such a context.

6.2 Limitations

This analysis faces several limitations. These limitations impact the development and interpretation of the results, although they do not substantially undermine the overall conclusions. The key limitations are as follows:

- Control for movement of people: Data on the movement of people are not available. The only relevant data accessible at the time of this analysis come from the International Organization for Migration (IOM). However, these data are not suitable for this study, as they do not provide information on the number of individuals who migrated from each oblast. Additionally, during the period under consideration, there were significant population movements both out of and back into each oblast, which cannot be accurately accounted for. Importantly, since the focus is on the impact of landmines and ERW on economic outcomes, the movement of people functions as a mediator in this context, making it a potentially inappropriate control variable.
- Reverse causation: There is a clear endogeneity issue present, as more affluent and economically productive regions may be more likely to be impacted by ERW. While this concern is partially addressed through the difference-in-differences approach and the inclusion of relevant control variables, it remains a limitation of the study, particularly with respect to CHA.

APPENDICES

A1.

Summary Statistics

Yearly nominal GDP (in million UAH)

	Obs	Mean	Median	Minimum	Maximum	25th pct	75th pct	SD
	All regions							
Yearly GDP pre-war	100	172,103.80	98,106.00	33,905.00	1,276,376.00	74,137.00	201,517.50	200,392.10
Yearly GDP during war	50	181,572.50	107,204.60	11,502.27	1,163,072.00	84,803.08	210,531.00	206,633.40
	Oblasts containing suspected hazardous area (SHA)							
Yearly GDP pre-war	40	176,141.90	135,602.50	55,152.00	582,363.00	82,250.00	237,842.50	117,834.60
Yearly GDP during war	20	150,194.50	105,532.30	23,762.54	471,141.30	78,425.29	191,455.90	117,000.10
	Oblasts containing confirmed hazardous area (CHA)							
Yearly GDP pre-war	36	176,314.10	113,696.50	55,152.00	582,363.00	80,167.50	244,999.00	123,908.20
Yearly GDP during war	18	151,793.50	99,959.57	23,762.54	471,141.30	77,337.53	210,531.00	123,580.80

Monthly exports pre- and post-war (in million USD)

	Obs	Mean	Median	Minimum	Maximum	25th pct	75th pct	SD
	All regions							
Yearly GDP pre-war	1,275	177.19	89.40	0.00	1,770.17	51.68	177.02	247.94
Yearly GDP during war	566	117.75	69.39	0.00	1,137.22	35.80	134.00	166.37
	Positive SHA regions							
Yearly GDP pre-war	500	221.93	140.05	0.00	1,335.03	65.76	292.93	224.01
Yearly GDP during war	210	110.28	64.86	0.00	1,002.42	34.42	134.00	139.93
	Positive CHA regions							
Yearly GDP pre-war	450	213.61	121.36	0.00	1,335.03	61.95	251.14	233.51
Yearly GDP during war	189	104.12	60.92	0.00	704.36	32.80	108.94	131.35

Monthly tax income pre-post war (in million USD, inflation adjusted)

	Obs	Mean	Median	Minimum	Maximum	25th pct	75th pct	SD
	All regions							
Yearly GDP pre-war	1,275	20.60	13.33	0.00	113.69	10.06	26.50	18.27
Yearly GDP during war	566	12.81	8.64	0.00	80.32	6.46	15.24	13.14
	Positive SHA regions							
Yearly GDP pre-war	500	23.47	16.26	6.19	85.63	11.61	31.02	15.19
Yearly GDP during war	210	13.45	8.88	1.33	50.14	6.86	17.44	11.26
	Positive CHA regions							
Yearly GDP pre-war	450	23.32	14.78	6.19	85.63	11.39	32.97	15.96
Yearly GDP during war	189	13.75	8.53	1.33	50.14	6.67	19.53	11.82

A2.

Regression output: GDP on CHA/SHA

	(1) GDP
CHA*POST	-39.59
	(33.73)
CHA	21.77
	(35.97)
SHA*POST	-0.140
	(0.100)
SHA	0.262**
	(0.100)
SHA squared	-0.295***
	(0.0423)
Observations	66
R-squared	0.307
Chem cont*POST	YES
Shr destr*POST	YES
People killed*POST	YES
People injured*POST	YES
Year*War intensity	YES

Note: Regression is run on a panel data set of oblasts at the year level. Year fixed effects are included. Observations are weighted by regional area. Robust standard errors are in parentheses. Significance level is *** p<0.01, ** p<0.05, * p<0.1.

Linear combination of all terms shown

	GDP	
	Coeff	*SE*
Linear-combination CHA:	-0.1732	0.0650
Linear-combination SHA:	-17.8231	46.0031

Regression output: tax revenues and exports on CHA/SHA

	(1) Tax Revenues	(2) Exports
CHA*POST	-46,432	17,106
	(40,560)	(581,174)
CHA	-38,242*	-595,533*
	(19,024)	(319,303)
SHA*POST	-230.7	84.83
	(175.7)	(2,220)
SHA	-102.8	-2,989*
	(140.2)	(1,703)
Observations	66	66
R-squared	0.307	0.300
Chem cont*POST	YES	YES
Shr destr*POST	YES	YES
People killed*POST	YES	YES
People injured*POST	YES	YES
Year*War intensity	YES	YES

Note: Regression run on a panel data set of oblasts at the year level. Year fixed effects are included. Observations are weighted by regional area. Robust standard errors are in parentheses. Significance level is *** p<0.01, ** p<0.05, * p<0.1.

Linear combination of all terms shown

	Tax Revenues		*Exports*	
	Coeff	*SE*	*Coeff*	*SE*
Linear-combination CHA:	-333.4652	90.7403	-2904.134	1265.404
Linear-combination SHA:	-84673.59	34725.56	-578427	463003.3

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