# Casualties of border changes: Evidence from nighttime lights and plant exit

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# Introduction

- International borders change over time.
- Besides geopolitical consequences, changes in borders—and in the ease with which they can be crossed—have substantial economic consequences.
- Market access affects the location and size of economic activity:
  - German division and reunification after WWII and population growth in border cities (Redding and Sturm, 2008);
  - Fall of the Iron Curtain and wage and employment growth in Austrian border municipalities and cities (Brülhart et al., 2012, 2018);
  - Division and reunification of Berlin after WWII; reorientation of land price and employment gradients (Ahlfeldt et al., 2015);

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- More granular data—nighttime lights (NTL) and firm-level data—to assess effects of market access on regional outcomes. For example, NTL to investigate:
  - the effects of sanctions in North Korea (Lee, 2018);
  - changes in border cities' GDP following African regional trade agreements (Eberhard-Ruiz and Moradi, 2019);
  - the 'dimming' effect of international borders on nighttime lights (Brülhart et al., 2022);
  - firm-level data to look at the eastern EU expansion effects on firms' sales and exports close to new external EU borders (Vermeulen, 2022).
- New findings emerging from finer spatial data:
  - market access effects in border regions are *highly localized*, usually less than 50 km;
  - effects *differ substantially* across locations, depending on initial exposure to other regions' economic activity (e.g., Yang et al., 2022);
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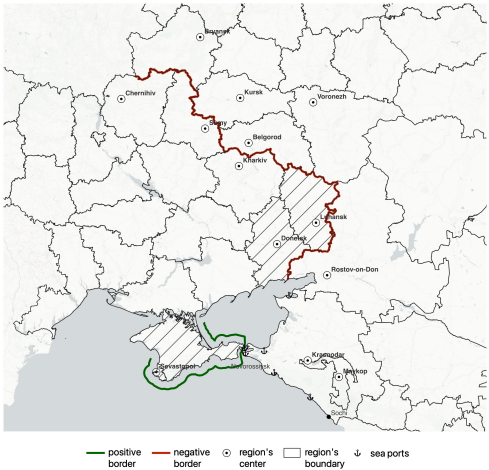
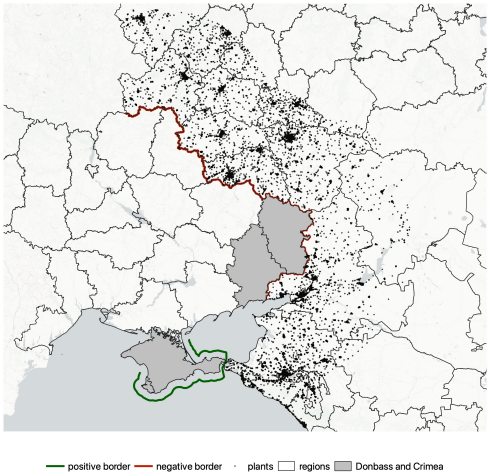
# Setting and main findings

- Annexation of Crimea in 2014 and the ensuing conflict (up to 2018) as a source of exogenous variation in market access for Russian border regions;
- Assessing the direct effect of the annexation is complicated: Western sanctions after 2014 affect growth and firm performance.
- We exploit differential exposure to changes in market access along the border (north vs south) to identify the economic effects.
- We also exploit the closure of local border crossings as a source of exogenous variation in cross-border labor movements.



# Setting and main findings

- We quantify the effects of border changes using NTL and georeferenced plant data.
- Regions with relatively deteriorating market access or more exposed to Ukraine pre-2014
  - *saw less growth in lights* (preferred: 3.4%-4% less growth in GDP; average across specifications: 5.2%);
  - *saw more plant exit*, about 1.5 pp increase.
- In northern regions, local cross-border labor movements may drive localized effects.



# Geopolitical context and timeline


- August 1991: Ukraine declares independence from USSR; border regions were historically highly integrated and remained so
- February 1995: agreement on state border checkpoints and simplified border procedures for cross-border commuting
- April 2004: ratification of formal border treaty
- Early 2012: initiation of the EU Association agreement
- November 2013: 'Euromaidan' following the decision to not sign the Association Agreement in favor of the Eurasian Economic Union.
- March 2014: annexation of Crimea by Russia
- April 2014: armed conflict erupts in the Donbass following the proclamation of two independent republics
- March 2015: Ukraine tightens border controls
- We cover the period 2006–2018

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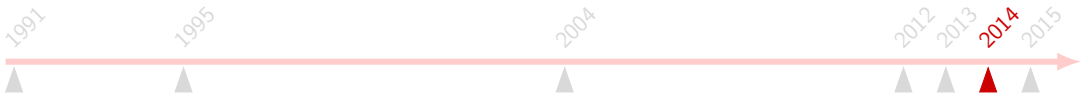


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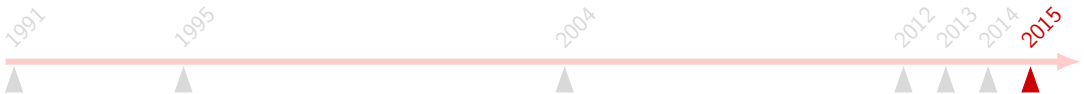


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# Data

## NTL and plant-level data

Harmonized nighttime lights, 2005–2018, digital number $\in [0, 63]$ (Li et al., 2020). Based on DMSP and VIIRS.

Ruslana and Interfax SPARK manufacturing plant-level databases: entry and exit date, status updates, industry code, de facto address. Geocoded using Yandex API.

## Key dependent variables

Cell-level ($1 \times 1$ km), raw NTL or lights-weighted regional GDP.

Plant-level exit status in year $t \in [2006, 2018]$, regular updates from the Unified State Register of Legal Entities.

# Exposure to activity in Ukraine and to border changes

## Main exposure measures

- Dummies for plants/cells less than 50, 100, or 150 kilometers from the border;
- Market potential measures, access to NTL or GDP in Ukraine, inversely weighted by distance;
- Relative crow-fly distance (distance from the positive border segment in the south to distance from the negative border segment in the north);
- Relative network distance on the main road system;
- Mean-centered latitude (continuous), or discretized latitude bands: South, Donbass, North.

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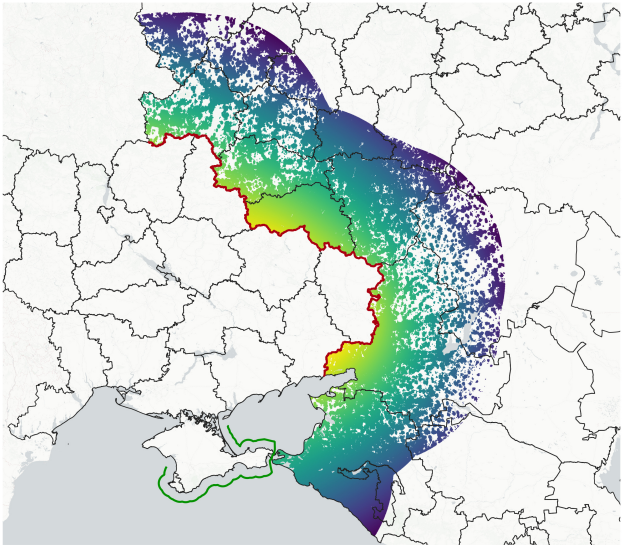
# Exposure to Ukrainian market potential, 2010–2013: NTL cells



# Empirical analysis

**Empirical strategy:**

- Estimate the effects of border changes using a 'DiD' framework: we compare less exposed cells or plants pre 2014 with more exposed cells/plants;
- Some cells/plants are more exposed to negative border 'changes' (Donbass, north) while others are more exposed to positive border changes (south) post 2014;
- We expect (and do find) worse outcomes for more exposed cells/plants after 2014.

**Robustness and mechanisms:**

- Many robustness checks and additional analyses to rule out potential confounders;
- Explore economic mechanisms behind the results

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# DiD: cell-level GDP and plant exit regressions

Our baseline specifications:

$$
\begin{aligned}
y_{i,t} &= \beta_0 + \gamma_1(\text{post}_{2014} \times \ln \text{minD}_i) + \gamma_2(\text{post}_{2014} \times \text{exp}_i) + \alpha_i + \delta_t + \varepsilon_{i,t}, \\
y_{p,t} &= \beta_0 + \gamma_1(\text{post}_{2014} \times \ln \text{minD}_p) + \gamma_2(\text{post}_{2014} \times \text{exp}_p) + \mathbf{X}_{p,t}\gamma_3 + \alpha_p + \delta_t + \varepsilon_{p,t}
\end{aligned}
$$

where

- $y_{i,t}$ is one plus log NTL-GDP (or NTL) of cell $i$ in year $t$;
- $y_{p,t}$ is a dummy that takes value 1 if plant $p$ exits in year $t$;
- $\ln \text{minD}_i$ is the minimum distance of cell $i$ from the border;
- $\text{exp}_i$ is the log one of our exposure measures;
- $\text{post}_{2014}$ is a dummy variable taking value 1 starting in 2014.

Our coefficient of interest is $\gamma_2$.

# Changes in cell-level GDP

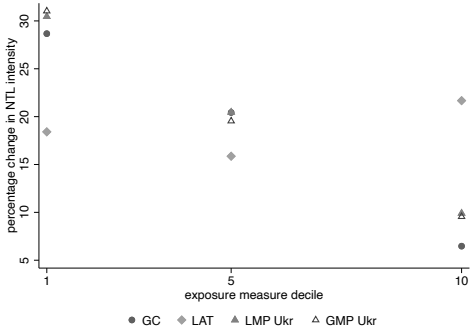
| | (1) distance band | (2) distance band | (3) LMP Ukr | (4) GMP Ukr | (5) GC | (6) LAT | (7) LAT bands |
|---|---|---|---|---|---|---|---|
| post2014 | 0.951[a] | 0.952[a] | 1.668[a] | 1.290[a] | 1.764[a] | 0.519[a] | 0.878[a] |
| | (0.002) | (0.002) | (0.033) | (0.030) | (0.012) | (0.006) | (0.007) |
| post2014 × band | -0.124[a] | | | | | | |
| | (0.002) | | | | | | |
| post2014 × band(positive) | | 0.430[a] | | | | | |
| | | (0.007) | | | | | |
| post2014 × band(negative) | | -0.172[a] | | | | | |
| | | (0.002) | | | | | |
| post2014 × ln minDist | | | 0.015[a] | 0.032[a] | -0.119[a] | 0.079[a] | 0.046[a] |
| | | | (0.002) | (0.002) | (0.002) | (0.001) | (0.001) |
| post2014 × Lat(Donbass) | | | | | | | -0.345[a] |
| | | | | | | | (0.004) |
| post2014 × Lat(North) | | | | | | | -0.245[a] |
| | | | | | | | (0.003) |
| post2014 × exposure | | | -0.081[a] | -0.058[a] | -0.211[a] | -0.031[a] | |
| | | | (0.002) | (0.002) | (0.002) | (0.000) | |
| Observations (cell-year) | 8,133,230 | 8,133,230 | 8,133,230 | 8,133,230 | 8,133,230 | 8,133,230 | 8,133,230 |
| *R*-squared | 0.675 | 0.677 | 0.676 | 0.676 | 0.678 | 0.676 | 0.677 |

# Plant exit

| | (1) distance band | (2) distance band | (3) LMP Ukr | (4) GMP Ukr | (5) GC | (6) ND | (7) LAT | (8) LAT bands |
|---|---|---|---|---|---|---|---|---|
| post2014 | 0.294[a] | 0.294[a] | 0.064[b] | 0.160[a] | 0.210[a] | 0.260[a] | 0.280[a] | 0.264[a] |
| | (0.003) | (0.003) | (0.031) | (0.029) | (0.008) | (0.006) | (0.006) | (0.007) |
| post2014 x band | -0.008[a] | | | | | | | |
| | (0.002) | | | | | | | |
| post2014 x band(positive) | | -0.030[a] | | | | | | |
| | | (0.004) | | | | | | |
| post2014 x band(negative) | | -0.005[a] | | | | | | |
| | | (0.002) | | | | | | |
| post2014 x ln minDist | | | 0.018[a] | 0.011[a] | 0.014[a] | 0.006[a] | 0.002[b] | 0.003[b] |
| | | | (0.002) | (0.002) | (0.001) | (0.001) | (0.001) | (0.001) |
| post2014 x Lat(Donbass) | | | | | | | | 0.003 |
| | | | | | | | | (0.003) |
| post2014 x Lat(North) | | | | | | | | 0.026[a] |
| | | | | | | | | (0.002) |
| post2014 x exposure | | | 0.013[a] | 0.008[a] | 0.012[a] | 0.005[a] | 0.003[a] | |
| | | | (0.002) | (0.002) | (0.001) | (0.001) | (0.000) | |
| Plant controls | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Observations (plant-year) | 528,147 | 528,147 | 528,147 | 528,147 | 528,147 | 528,147 | 528,147 | 528,147 |
| *R*-squared | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 | 0.222 |

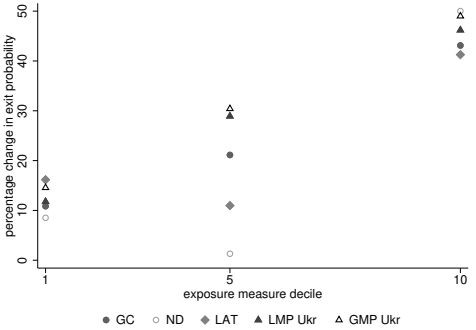
# Changes in outcomes by exposure decile

(a) Cell-level NTL




NTL increased 20–25% less for most exposed cells, about 3.4%-5.2% difference in GDP growth.

(b) Plant exit




About 30–35% more exit (1.5 pp of 7.2% baseline) for most exposed plants.

## Robustness checks

Our results are robust to a large number of robustness checks:

- Separate minimum distance measures to northern and southern borders.
- Raw nighttime lights, 2013 GDP-NTL weighted lights as dependent variables;
- Trimming of cells that have zero light;
- Years 2012–2013 as alternative treatment date (initiation of EU accession talks, Euromaidan) yield qualitatively similar effects, but smaller magnitudes;
- Quarterly nighttime lights (VIIRS from 2012–2018) and plant-level data;
- Estimates with industry-year fixed effects for plant exit.
- Exclude plants that exit because of accession and mergers.

# The role of market access: a causal relationship?

Possible confounding factors we try to rule out (see the paper for details):

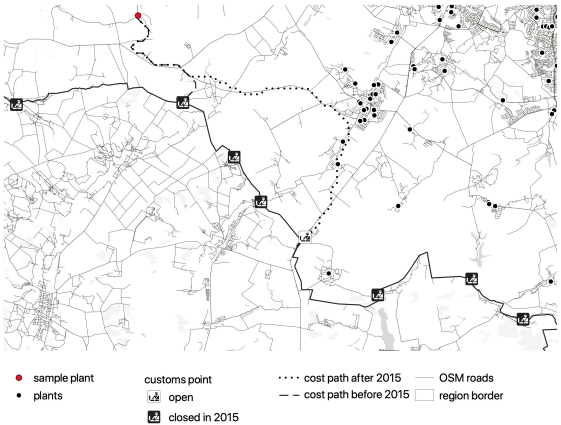
- Unequal regional effects of the 2014 sanctions which could hit more strongly the north if specialized in sanctioned industries;
- Potential regional effects of the 2014 Winter Olympic Games in Sochi;
- Public investments or politically motivated subsidies to private firms that target more the south;
- More negative expectations about future conflict in the north;
- Disruptions in cross-border electricity trade that affects lights and could also affect more strongly firms that are energy intensive.

# More evidence on market access: the local effects of closed border crossings

Zoom on the northern regions (Bryansk, Belgorod, Voronezh, and Kursk):

- We assembled a novel dataset on local border crossings (from the agreement between Russia and Ukraine to facilitate cross-border movements);
- *No trade through these points* (residents of border regions can only move goods not intended for production or other commercial activities across the border);
- Historically an economically highly integrated region (Zhukov, 2016); substantial local cross-border movement of labor (Kolosov et al., 2016; Zayats et al., 2017);
- In March 2015, shutdown of local border crossings (the international crossings, serving mainly big cities, remained open); provides variation in the distance to nearest border crossing.

# Closing of local border crossings and changes in distance travelled




- Estimate effects of an increase in distance to nearest open border X-ing;
- Use more granular data (quarterly NTL and plant exit series, treatment starting March 2015; VIIRS NTL $500 \times 500$ meters cells);
- We find negative effects on NTL, especially in treated areas of big cities;
- Eberhard-Ruiz and Moradi (2019) find localized effects of small-scale cross-border trade. Our findings suggest that local cross-border labor movements matter too.
- No statistically significant effect on plant exit

# Changes in NTL and distance to border crossings, 50km

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | Equipped X-ings | | All X-ings | |
| | GC | GCW | GC | GCW |
| post2015-Q1 | 0.080$^a$ | 0.077$^a$ | 0.082$^a$ | 0.076$^a$ |
| | (0.000) | (0.000) | (0.000) | (0.000) |
| post2015-Q1 × ΔcrossingDistance | -0.020$^a$ | -0.080$^a$ | -0.019$^a$ | -0.085$^a$ |
| | (0.000) | (0.002) | (0.000) | (0.003) |
| post2015-Q1 × bigCity | 0.364$^a$ | 0.356$^a$ | 0.393$^a$ | 0.380$^a$ |
| | (0.014) | (0.013) | (0.024) | (0.017) |
| post2015-Q1 × ΔcrossingDistance × bigCity | -2.978$^a$ | — | -1.466$^b$ | -5.381$^b$ |
| | (0.606) | — | (0.580) | (2.171) |
| Cell fixed effects | ✓ | ✓ | ✓ | ✓ |
| Year-quarter fixed effects | ✓ | ✓ | ✓ | ✓ |
| Observations | 8,216,500 | 8,216,500 | 8,216,500 | 8,216,500 |
| $R$-squared | 0.875 | 0.875 | 0.875 | 0.875 |

# Conclusion

- We leverage spatially and economically disaggregated data (nighttime lights and georeferenced plants) to contribute to a recent literature on the regional effects of economic integration and conflict.
- We confirm the robustness of new key insights from that literature:
  - spatial effects of changes in market access are highly localized, effects vary substantially across places and firms;
  - highly localized effects may be partly driven by economic activity that is very sensitive to distance frictions;
- Less growth in lights and more exit in relatively more exposed regions: 3.4%-5.2% difference in GDP growth, about 30%–35% (1.5 pp) difference in plant exit.
- Direct economic costs of the annexation sizeable in some regions, redistributive effects; but DiD and sanctions do not allow for aggregate assessment.