Supplementary file for Network Agency: An Agent-based Model of Forced Migration from Ukraine

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1 Model Dynamics

$$F_i(t) = \begin{cases} \sum_{\hat{t}=0}^{t} \theta^{t-\hat{t}}\, g(C(\hat{t}), a_i) & \text{if } M_k(t) = 0 \\ F_i(t-1) & \text{otherwise} \end{cases} \tag{1}$$

where,

$$g(C(t), a_i) = \sum_{c_j \in C(t)} \beta \frac{s_j \times b_i}{dis(y_j, x_i^t)^{\delta}}$$

$$P_k(t) = \begin{cases} \underset{a_i \in \eta^{-1}(h_k)}{\text{Avg}} \{\sigma(F_i(t))\} & \text{if } M_k(t) = 0 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

where,

$$\sigma(x) = \frac{1}{1 + Q\, e^{-\tau x}}$$

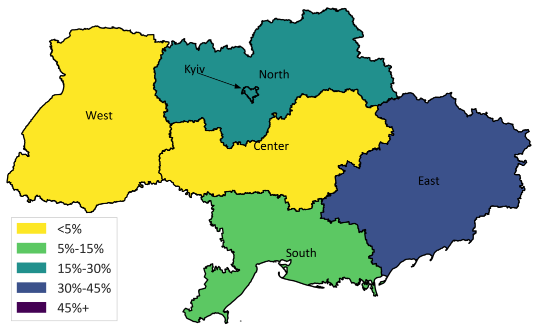
$$M_u(t) = \begin{cases} 1 & \text{if } M_u(t-1) = 1 \\ 1 & \text{if } M_u(t-1) = 0 \text{ and } \lambda \psi_u^1(t-1) + (1-\lambda)\psi_u^2(t-1) \geq \pi \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

Algorithm 1 Network model

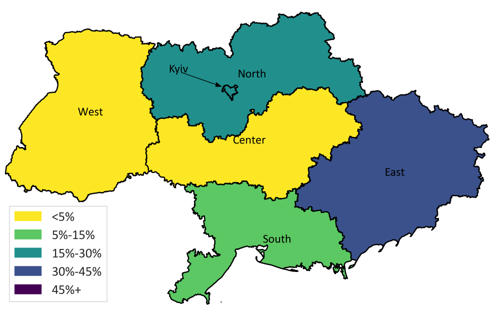
$H \leftarrow$ Set of household agents
$r \leftarrow$ Max edge length
$p \leftarrow$ Max short edge length
$q \leftarrow$ Max number of long edges
$\alpha \leftarrow$ Long edge selection parameter
$E \leftarrow []$
for $h \in H$ **do**
  $H' \leftarrow$ Set of households within r radius of h
  $E \leftarrow E + KSW(H', p, q, \alpha)$
end for
return E
procedure KSW(H, p, q, α)
  $E \leftarrow []$
  for (u, v) pair $\in H$ **do**
    if $dis(u, v) <= p)$ **then**
      Add (u, v) to E
    else
      if $deg(u) < q$ **then**
        Add (u, v) to E with probability $dis(u, v)^{-\alpha}$
      end if
    end if
  end for
end procedure

Algorithm 2 Network agency ABM

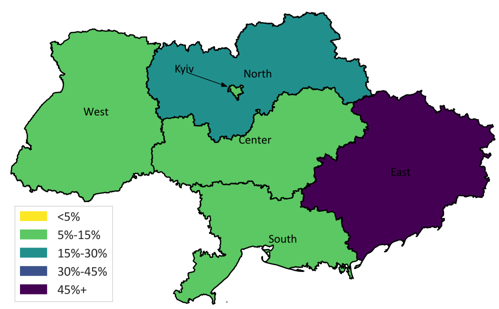
Calculate $F_i(0)$ based on Equation 1, $\forall a_i \in A$
Calculate $P_k(0)$ based on Equation 2, $\forall h_k \in H$
for $t = 1$ to T **do**
  Calculate $M_k(t)$ based on Equation 3 $\forall h_k \in H$
  for $h_k \in H$ **do**
    Mark h_k as Refugee with Prob γ or IDP with Prob $1-\gamma$ if $M_k(t) = 1$
  end for
  Calculate $F_i(t)$ based on Equation 1, $\forall a_i \in A$
  Calculate $P_k(t)$ based on Equation 2, $\forall h_k \in H$
end for



(a) IOM Survey

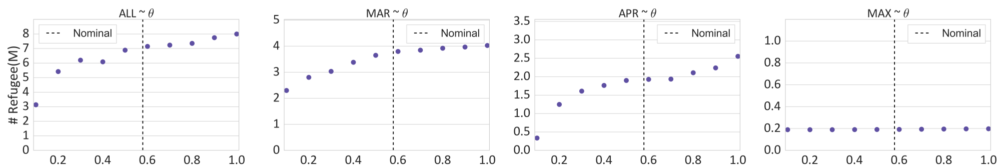


(b) ABM-NA

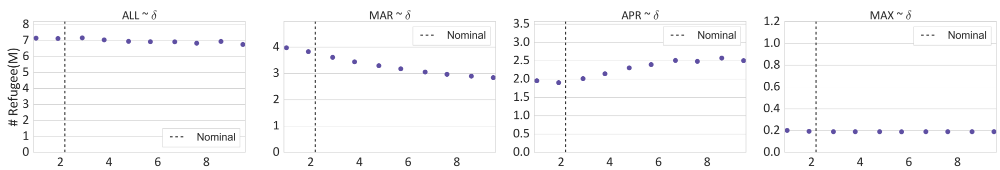


(c) ABM-IA

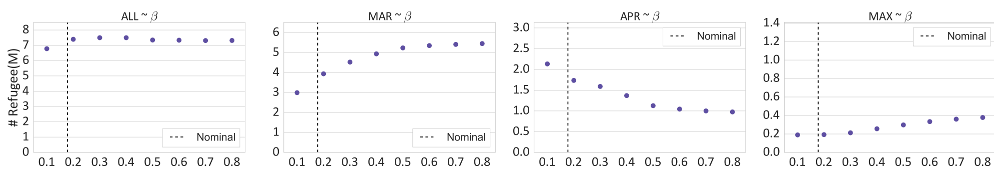
Figure 1: Map for % origin of IDP based on their Macro-region.



(a) Discounting factor parameter θ

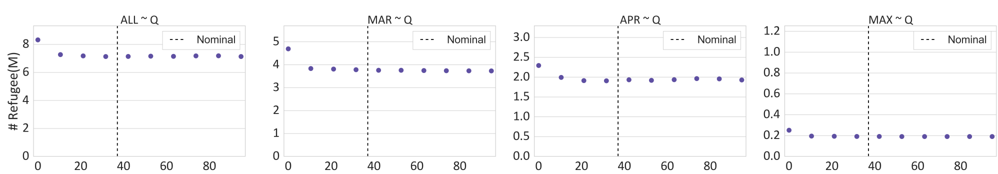


(b) Distance decay parameter δ

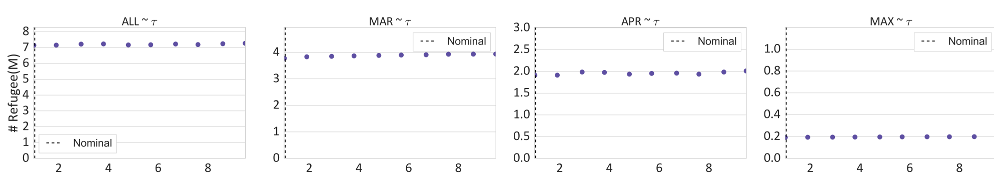


(c) Fear-scaling parameter β

Figure 2: Main effect plot from local sensitivity analysis for parameters associated with Perception function

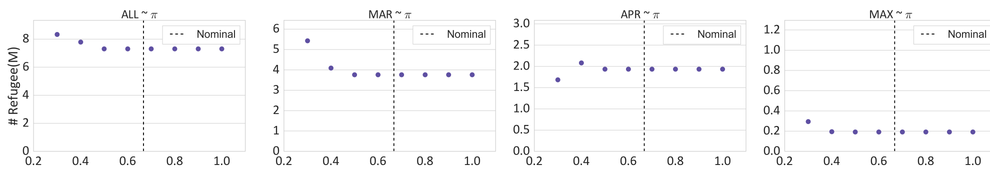


(a) No-fear migration control Q

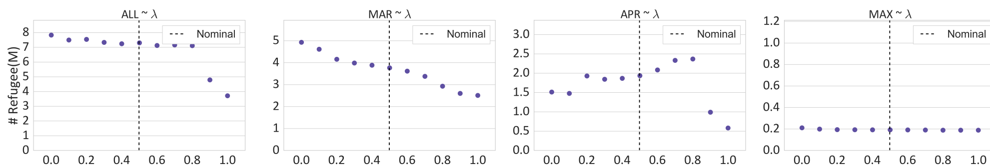


(b) Growth rate parameter τ

Figure 3: Main effect plot from local sensitivity analysis for parameters associated with representation function



(a) Peer threshold π



(b) In-peer weight λ

Figure 4: Main effect plot from local sensitivity analysis for parameters associated with peer influence function

2 Choosing b_i for different demographic groups

Table 1: Risk-perceivedness for the agents

Group	b_i
Adult Male	0.02 (without family) or 0.05 (with family)
Adult Female	0.2 (without family) or 0.8 (with family)
Elderly	0.15 (without family) or 0.2 (with family)
Child	0.5 (without family) or 0.8 (with family)

The individuals are divided into four different demographic groups based on their age and sex (elderly, child, adult male, adult female). Afterward, taking into consideration whether each agent is part of a family or not, they are assigned b_i values as shown in Table 1. Males are given low risk-perceivedness since there were policies in place for them to stay back in order to participate in war. Also, agents with family ties are given more weights. These values are based on discussions with researchers of political science and consensus among authors.

Table 2: Weights of different types of events

Event Type	W_j
Explosions	3
Battles	2
Violence against civilians	2
Protest	1
Riots	1
Others	0

Table 3: Range of parameters for OFAT and LHS

Parameter	Nominal Value	Search Space
Discounting factor θ	0.58	(0,1.0]
Distance Decay δ	2.18	[1.0,10.0]
No-Fear control Q	37.06	(0.0,100.0]
Growth rate τ	1.03	[1.0,10.0]
Fear scale β	0.18	(0,1]
Peer threshold π	0.67	[0.3,1.0]
Inside peer weight λ	0.5	(0,1)

3 Calculation of event severity

The severity s_j is calculated as $s_j = W_j \times I_j$. Here, I_j is the fatality of event j. This is recorded in the ACLED data as a field. W_j is a weight associated with the event type as defined in Table 2. The weights are based on weights of different types of events defined in GDELT-CAMEO codebook [1].

References

[1] Carammia, M., Iacus, S. M., and Wilkin, T. Forecasting asylum-related migration flows with machine learning and data at scale. *Scientific Reports 12*, 1 (2022), 1457.