

Algorithm 1: Smart Green Manufacturing ABM with SVI-driven Emergent Demand

Require: Grid of patches \mathcal{P} ; initial numbers (N_S^0, N_M^0) ; capacity limits (\bar{N}_S, \bar{N}_M) ; base parameters $(\gamma, \delta, \epsilon, p_d, p_0, \eta, D_0)$; fiscal parameters $(B_0, F_0, \kappa_g, \kappa_{ai}, \tau_c, \tau_e)$; simulation horizon T ; recording interval Δt .

Ensure: Time series of $(N_M, N_S, |\mathcal{P}_g|, \bar{a}, \bar{g}, p, B, F, S, D, \text{SVI})$.

- 1: **Initialization:** $t \leftarrow 0$, government budget $B \leftarrow B_0$, transition fund $F \leftarrow F_0$.
- 2: Initialize patches: for each $p \in \mathcal{P}$, $p.\text{color} \sim \text{Bernoulli}(0.2)$ (green if 1, else brown); if brown then $p.\text{countdown} \sim \text{Unif}\{0, \dots, 59\}$ else 0.
- 3: Create suppliers \mathcal{S} with $|\mathcal{S}| = N_S^0$; create manufacturers \mathcal{M} with $|\mathcal{M}| = N_M^0$.
- 4: Assign initial attributes: suppliers $c_s \leftarrow 16$; manufacturers $c_m \leftarrow 30$, $a_m \leftarrow 0$, $g_m \leftarrow 1$.
- 5: Open CSV and write header.

6: **for** $t = 1$ to T **do**

7: **if** $|\mathcal{S}| + |\mathcal{M}| = 0$ **then**

8: **break**

9: **end if**

(A) Supply and SVI-driven demand

- 10: $S \leftarrow |\mathcal{S}|$ ▷ total supply proxy
- 11: $\bar{q} \leftarrow \begin{cases} \frac{1}{|\mathcal{M}|} \sum_{m \in \mathcal{M}} a_m, & |\mathcal{M}| > 0 \\ 0, & \text{otherwise} \end{cases}$
- 12: $r_g \leftarrow \frac{|\mathcal{P}_g|}{|\mathcal{P}|}$ ▷ $\mathcal{P}_g = \{p \in \mathcal{P} : p.\text{color} = \text{green}\}$
- 13: $h_s \leftarrow \begin{cases} \frac{|\{s \in \mathcal{S} : c_s > 5\}|}{|\mathcal{S}|}, & |\mathcal{S}| > 0 \\ 0.1, & \text{otherwise} \end{cases}$
- 14: $\text{SVI} \leftarrow 0.40 \bar{q} + 0.40 r_g + 0.20 h_s$
- 15: $D \leftarrow D_0 \cdot (1 + 3.2 \text{SVI})^2$ ▷ emergent demand

(B) Price formation with stochastic perturbation

- 16: $\tilde{p} \leftarrow p_0 \cdot \left(\frac{D}{\max(1, S)} \right)^\eta$
- 17: $\xi \sim \text{Unif}(0.98, 1.02)$
- 18: $p \leftarrow \text{clip}(\tilde{p} \cdot \xi, 0.6, 2.5)$

(C) Aggregate AI statistics

- 19: $\bar{a} \leftarrow \begin{cases} \frac{1}{|\mathcal{M}|} \sum_{m \in \mathcal{M}} a_m, & |\mathcal{M}| > 0 \\ 0, & \text{otherwise} \end{cases}$
- 20: $\bar{g} \leftarrow \begin{cases} \frac{1}{|\mathcal{M}|} \sum_{m \in \mathcal{M}} g_m, & |\mathcal{M}| > 0 \\ 1, & \text{otherwise} \end{cases}$

(D) Public finance and subsidy scaling

- 21: $n_{\text{low}} \leftarrow |\{m \in \mathcal{M} : a_m < 0.5\}|$
- 22: $R_c \leftarrow 0.8 \tau_c n_{\text{low}}$ ▷ carbon-tax revenue
- 23: $R_e \leftarrow \tau_e |\mathcal{M}|$ ▷ energy-tax revenue
- 24: $F \leftarrow F + 0.4 R_c + 0.3 R_e$ ▷ accumulate transition fund
- 25: $r_g \leftarrow \frac{|\mathcal{P}_g|}{|\mathcal{P}|}$; $\rho_F \leftarrow F/100$
- 26: $\lambda \leftarrow (0.15 + 0.2(1 - r_g)) \cdot (1 + \min(\rho_F, 2))$ ▷ release rate
- 27: $u \leftarrow \min(\lambda F, 0.9 F)$ ▷ released amount
- 28: $F \leftarrow F - u$; $B \leftarrow \max(B + u, 150)$
- 29: $\alpha \leftarrow \min(1, \frac{B}{200})$
- 30: $\kappa'_g \leftarrow \alpha \kappa_g$; $\kappa'_{ai} \leftarrow \alpha \kappa_{ai}$

(E) Manufacturers' dynamics

- 31: **for all** $m \in \mathcal{M}$ **do**

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32:      Movement: choose target patch  $p^*$  uniformly from brown patches within radius 15
    if nonempty; move step 1 toward  $p^*$ , else random turn  $\theta \sim \text{Unif}(-25^\circ, 25^\circ)$  and move 0.5.
33:      Competitiveness update:
34:      if  $m$  is on green patch then  $c_m \leftarrow c_m + 0.9$ 
35:      end if
36:      if  $m$  is on brown patch then
37:           $p.\text{countdown} \leftarrow p.\text{countdown} - 5a_m$ 
38:          if  $p.\text{countdown} \leq 0$  then set  $p$  green and  $p.\text{countdown} \leftarrow 0$ 
39:          end if
40:      end if
41:      Spillover to nearby suppliers:
42:      for all  $s \in \mathcal{S}$  within radius 3 of  $m$  do
43:           $c_s \leftarrow c_s + 0.25 a_m$ 
44:      end for
45:       $c_m \leftarrow c_m - 0.3 + \delta a_m$ 
46:      Generation upgrade (discrete):
47:      if  $c_m > 8 \wedge a_m > 0.7$  then
48:           $C_{\text{gen}} \leftarrow 15 + 6g_m$ 
49:          if  $c_m > C_{\text{gen}}$  then
50:               $c_m \leftarrow c_m - C_{\text{gen}}; g_m \leftarrow g_m + 1$ 
51:               $a_m \leftarrow 0.6a_m + 0.3$ 
52:          end if
53:      end if
54:      Regular AI upgrade (continuous):
55:      if  $c_m > 4 \wedge a_m < 1$  then
56:           $C_{ai} \leftarrow 8 + 12a_m$ 
57:          if  $c_m > C_{ai}$  then
58:               $c_m \leftarrow c_m - C_{ai}; a_m \leftarrow \min(1, a_m + 0.09)$ 
59:          end if
60:      end if
61:      Knowledge diffusion (pairwise stochastic learning):
62:       $\mathcal{N}_m \leftarrow \{j \in \mathcal{M} : \text{dist}(m, j) \leq 7 \wedge a_j > 0.1\}$ 
63:      if  $\mathcal{N}_m \neq \emptyset$  then
64:          pick  $j \sim \text{Unif}(\mathcal{N}_m); d \leftarrow \text{dist}(m, j)$ 
65:           $\pi \leftarrow \frac{a_j}{1.5+0.5d}$ 
66:           $u \sim \text{Bernoulli}(\pi)$ 
67:          if  $u = 1$  then  $a_m \leftarrow \min(1, a_m + 0.05)$ 
68:          end if
69:      end if
70:      Policy support (stochastic subsidies):
71:      if  $m$  on green patch  $\wedge B \geq \kappa'_g$  then
72:           $u \sim \text{Bernoulli}(0.3)$ 
73:          if  $u = 1$  then  $c_m \leftarrow c_m + \kappa'_g; B \leftarrow B - \kappa'_g$ 
74:          end if
75:      end if
76:      if  $a_m > 0.3 \wedge B \geq \kappa'_{ai}$  then
77:           $u \sim \text{Bernoulli}(0.3)$ 
78:          if  $u = 1$  then  $c_m \leftarrow c_m + \kappa'_{ai}; B \leftarrow B - \kappa'_{ai}$ 
79:          end if
80:      end if
81:      Backwardness tax (after warm-up):

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82:     if  $a_m < 0.4 \wedge t > 50$  then  $c_m \leftarrow c_m - 0.8\tau_c$ 
83:     end if
84:     Reproduction (firm entry):
85:     if  $c_m > 10 \wedge |\mathcal{M}| < \bar{N}_M$  then
86:          $u \sim \text{Bernoulli}(0.015)$ 
87:         if  $u = 1$  then
88:              $c_m \leftarrow c_m/2$ 
89:             Create new manufacturer  $\hat{m}$  near  $m$  with  $(a_{\hat{m}}, g_{\hat{m}}, c_{\hat{m}}) \leftarrow (0.3, 1, 15)$ 
90:         end if
91:     end if
92:     Exit: if  $c_m < 0$  then remove  $m$  from  $\mathcal{M}$ .
93: end for
(F) Suppliers' dynamics
94: for all  $s \in \mathcal{S}$  do
95:     Random walk:  $\theta \sim \text{Unif}(-25^\circ, 25^\circ)$ ; move 0.7.
96:     if  $s$  on green patch then
97:          $c_s \leftarrow c_s + 1 + \gamma \bar{a}$ 
98:         Reproduction probability:
99:          $p_b \leftarrow 0.012$ 
100:         $p_r \leftarrow p_b \cdot p^{0.7}$ 
101:         $f_{\text{sat}} \leftarrow 1 - (|\mathcal{S}|/\bar{N}_S)^{0.3}$ 
102:         $f_{\text{price}} \leftarrow (p/1.0)^{0.5}$ 
103:         $f_{\text{dens}} \leftarrow 1 - \min(1, |\mathcal{S}|/\bar{N}_S)$ 
104:         $p_s \leftarrow p_r \cdot f_{\text{dens}} \cdot f_{\text{sat}} \cdot f_{\text{price}}$ 
105:        if  $c_s > 12 \wedge \frac{|\mathcal{S}|}{\max(1, |\mathcal{M}|)} < 10$  then
106:             $u \sim \text{Bernoulli}(p_s)$ 
107:            if  $u = 1$  then
108:                 $c_s \leftarrow c_s/2$ 
109:                Create new supplier  $\hat{s}$  near  $s$ 
110:            end if
111:        end if
112:    else
113:         $c_s \leftarrow c_s - 0.65$  ▷ brown patch penalty
114:    end if
115:    Exit: if  $c_s < 0$  then remove  $s$  from  $\mathcal{S}$ .
116: end for
(G) Patch-level green transition acceleration
117: for all brown patch  $p \in \mathcal{P}$  do
118:      $p.\text{countdown} \leftarrow p.\text{countdown} - 0.1 + 0.5\epsilon \bar{a}$ 
119:     if  $p.\text{countdown} \leq 0$  then set  $p$  green and  $p.\text{countdown} \leftarrow 0$ 
120:     end if
121: end for
(H) External shocks
122:  $u \sim \text{Bernoulli}(p_d)$ 
123: if  $u = 1$  then
124:     Select affected set  $\mathcal{A} \subset \mathcal{P}$  uniformly with  $|\mathcal{A}| = \lfloor 0.04|\mathcal{P}| \rfloor$ 
125:     for all  $p \in \mathcal{A}$  do
126:         set  $p$  brown;  $p.\text{countdown} \leftarrow p.\text{countdown} + \zeta$ , where  $\zeta \sim \text{Unif}\{0, \dots, 29\}$ 
127:     end for
128:     for all  $m \in \mathcal{M}$  do  $c_m \leftarrow 0.75 c_m$ 
129: end for

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130:     end if
    (I) Recording
131:     if  $t \bmod \Delta t = 0$  then
132:         Append CSV row:  $(t, |\mathcal{M}|, |\mathcal{S}|, |\mathcal{P}_g|, \bar{a}, \bar{g}, p, B, F, S, D, \text{SVI})$ 
133:     end if
134: end for

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