Detailed Simulation Algorithm

Phase 1: Selection of Simulation Parameters

- **Population Size (N):** given studies do small population sizes: 1000 in [11], up to 5000 in [6]. We offer a slider to toggle.
- **Number of Simulation Time Steps (T):** the given studies choose timesteps in the range of 50 [11] to a 100 [6]. These timesteps represent years.
- **Number of Simulation Runs:** the simulation can be repeated numerous times to provide aggregate scores (see final metric definitions in Phase 4) across various scenarios.
- **Audit Rate:**
  - From the Jaarreportage 2024, the audit rate for private individuals (if including manual checks and automated corrections) is 2.4%. If only including manual audits, it is 0.91% [7]. As per suggestion from client, we set a default value of 1%. This can be toggled.
  - From the Jaarreportage 2024, the audit rate for MKBs (micro-, small- and medium- businesses) is 0.46% [7]. As per suggestion from client, we set a default value of 1%. This can be toggled.
- **Audit Strategy:** We offer three options:
  - Random: Uniform draw within given category (private/business).
  - Risk: Percent of agents within business category with top base risk scores will be selected. Within private individuals, random draw.
  - Network: Percent of agents within given category (private/business) with highest closeness centrality, noted as key factor by [6].
- **Social Influence Coefficient (ω)**: Strength of social influence, modeled as a numerical value from 0 to 1 [11]. 1 = Dishonest agent adjusts its subjective audit probability and percentage "evasion" to fully equal median of neighbors [11]. 0 = Dishonest agent's subjective audit probability and evasion choice are independent of neighbors.
- **Boost Perceived Service Orientation**: To represent service-orientation boosting interventions, we provide the option to toggle the default mean for the perceived service orientation of the agents by up to 1 point (plus or minus) on the Likert scale from 1 to 5. Defaults are assigned based on [8]) Q10: For private individuals: mean 3.22, sd 0.68 [8]. For businesses: mean 3.18, sd 0.67 [8]. Here the simulator can boost or decrease these.
- **Boost Perceived Trustworthiness**: To represent trust-boosting interventions, we provide the option to toggle the default mean for the perceived trust of the agents by up to 1 point (plus or minus) on the Likert scale from 1 to 5. Defaults are assigned based on [8]) Q11: For private individuals: mean 3.37, sd 0.69 [8]. For businesses: mean 3.37, sd 0.69 [8]. Here the simulator can boost or decrease these.
- **Fine Rate (f)**: All non-compliant agents will be subject to he same fine rate in this simplified model. Fine rate is defined as a multiplier upon tax rate, such that **fine rate * tax rate * undeclared amount** must be paid by non-compliant agents. Set by default to 3.
- **Tax Rate (t)**: All agents will be subject to the same tax rate in this simplified model. Tax rate is also part of the calculation of any fines on non-compliant agents: **fine rate * tax rate * undeclared amount** must be paid in addition to levied tax on declared income. Set by default to 0.3.

Phase 2: Initialization of Agents (t=0)

- **Initialize fixed general parameters for all agents:**
  - **Agent Occupation (o_i):** Either "private individual" or "business". We calculate the ratio between "Total male and female 15 to 74 years Labour force" and "Self-employed entrepreneur, all incomes" as defined by CBS: approximately 0.134% of Dutch people who qualify to be part of the labor force were self-employed in 2024 [2, 3]. However, client notes that this may be not correctly representative of the population and suggest a toggleable default value of 10%.
  - **Agent Type (τ_i):** First assign a Likert scale score using normal distribution clamped between 1 to 5 based on [8] Q13: For private individuals, assign using normal distribution with mean 3.87, sd 0.64 [8]. For businesses, assign with normal distribution: mean 4.07, sd 0.60 [8]. A score < 3 is taken as "**dishonest**" (more inclined towards non-compliance than compliance), while a score > 3 is taken as "**honest**" (more inclined towards compliance than non-compliance).
  - **Personal Norms (PN_i):** Assign using normal distribution clamped between 1 to 5 based on [8]) Q7: For private individuals, assign using normal distribution with mean 3.40, sd 1.15 [8]. For businesses, assign with normal distribution: mean 3.82, sd 1.04 [8].
  - **Risk Aversion (r_i):** This is sampled from a normal distribution defined clamped between 0.5 to 5: Mean: 2.0, Std: 1.0, Range: [0.5, 5.0]. These values are currenlty arbitrary and must be refined through further research! Our code allows a possibility to additionally define sector-specific risk aversion distributions for SMEs (currenlty undefined), such that the method checks if the agent's specific sector has a custom risk aversion configuration. If defined, it re-samples the parameter using the sector's specific mean and standard deviation.
- **Initialize fixed parameters only for private individuals:**
  - **Income i_i:**: Drawn from **lognormal** distribution to allow for long tail and only positive values, using mean 41.000 EUR (2023 mean equivalised income from CBS [4]), standard deviation estimated as 5.000 EUR.
- **Initialize fixed SME parameters only for businesses:**

  Developer Note: Make reference to existing SME parameter initialization script by Dies de Haan for exact implementation details.
  - **Size Class (S_i):** Sampled based on EU definitions [5] and CBS distribution patterns [10]: Micro (1–9 employees, $P = 0.82$), Small (10–49 employees, $P = 0.14$), and Medium (50–249 employees, $P = 0.04$).
  - **Turnover** (Tu_i) is drawn uniformly from size-specific ranges (Micro: 80k–400k, Small: 400k–2.5mil, Medium: 2.5mil–20mil) [10]).
  - **Sector (C_i):** Assigned using Dutch SBI head categories (e.g., Retail, Hospitality, Construction) drawn from a categorical distribution reflecting the Dutch SME population structure [10].
  - **Branch (B_i):** Drawn uniformly from a detailed list of business types (e.g., 'Kebabzaak', 'Taxibedrijf') specific to the assigned Sector (C_i). [10]
  - **Cash Intensity (K_i):** Boolean flag ($K \in \{yes, no\}$). Deterministically set to 'yes' for specific cash-reliant branches (e.g., Kebab shop, Nail salon). For others, sampled with probability dependent on sector: ≈ 0.6 for Hospitality/Retail, ≈ 0.1 for others. [10].
  - **Digitalisation (D_i):** Level ($D \in \{low, medium, high\}$) sampled per sector based on CBS adoption trends [10]. Sectors like ICT have high probability of $D = high$; Hospitality/Construction have higher probability of $D = low$ [10].
  - **Fiscal Advisor (F_i):** Boolean flag ($F \in \{yes, no\}$). Modeled with a base probability of $\approx 40\%$, increasing with larger firm size and higher digitalisation levels.
  - **Audit History**: The variable $H \in \{\text{geen}, \text{administratief}, \text{boekenonderzoek}\}$ represents historical interactions with the tax authority. Based on public Belastingdienst annual reports and Court of Audit analyses, which indicate that only a small minority of Dutch SMEs are subject to full audits, the prior control status is sampled from the following distribution [7]:

$$P(H) = \begin{cases} 0.75 & \text{for } H = \text{geen (no control)} \\ 0.18 & \text{for } H = \text{administratief (admin check)} \\ 0.07 & \text{for } H = \text{boekenonderzoek (books audit)} \end{cases} \quad (1)$$

In the simulation, the existence of prior controls acts as a mitigating factor in the risk model. Specifically, historical controls reduce the calculated base risk score (R_{base}), with a stronger reduction applied for a full books audit compared to an administrative check.

– **Base Risk Score (R_{base}):** The base risk score (R_{base}) represents the probability of non-compliance before specific error types are determined. It is calculated in two steps: first by computing a raw score (R_{raw}) based on additive adjustments to a baseline of 0.1, and second by clamping the result within a realistic probability range. This score calculation is **self-designed and arbitrary**: the coefficients must be refined by the Belastingsdienst through more granular research into compliance risk correlation with these factors!

$$R_{raw} = 0.20 + \delta_{sector} + \delta_{branch} + \delta_{size} + \delta_{cash} + \delta_{digi} + \delta_{adv} + \delta_{hist} \quad (2)$$

Where the adjustment factors (δ) are defined as follows:

$$\delta_{sector} = \begin{cases} +0.20 & \text{if High Risk Sector (e.g., Construction, Hospitality)} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_{branch} = \begin{cases} +0.10 & \text{if High Risk Branch (e.g., Kebab shop, Taxi)} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_{size} = \begin{cases} +0.10 & \text{if Micro (1–9 employees)} \\ -0.05 & \text{if Medium (50–249 employees)} \\ 0 & \text{if Small (10–49 employees)} \end{cases}$$

$$\delta_{cash} = \begin{cases} +0.10 & \text{if Cash Intensive} \\ 0 & \text{otherwise} \end{cases}$$

$$\delta_{digi} = \begin{cases} -0.10 & \text{if Digitalisation is High} \\ +0.05 & \text{if Digitalisation is Low} \\ 0 & \text{if Digitalisation is Medium} \end{cases}$$

$$\delta_{adv} = \begin{cases} -0.10 & \text{if Has Fiscal Advisor} \\ +0.05 & \text{if No Fiscal Advisor} \end{cases}$$

$$\delta_{hist} = \begin{cases} -0.10 & \text{if Prior Audit (Boekenonderzoek)} \\ -0.03 & \text{if Prior Admin Check} \\ 0 & \text{if No Prior Control} \end{cases}$$

Finally, the score is clamped to ensure it remains within the bounds $[0.05, 0.90]$:

$$R_{base} = \max(0.05, \min(0.90, R_{raw})) \quad (3)$$

- **Initialize dynamic parameters for all agents:**
  - **Subjective Audit Probability (p_i^t):** Assign using normal distribution clamped between 0 to 100 based on[8]) Q6 (this assumes actual noncompliance):
    - For private individuals, Mean Calculation: $(3.43 - 1)25 = 2.4325 =$ **60.75**. SD Calculation: $0.8825 =$ **22.00**.
    - For businesses, Mean Calculation: $(3.54 - 1)25 = 2.5425 =$ **63.50**. SD Calculation: $0.9225 =$ **23.00**.
  - **Perceived Trustworthiness ($PT_{i,0}$) of Belastingsdienst:** Assign using normal distribution clamped between 1 and 5 based on [8]) Q11: For private individuals, assign using normal distribution with mean 3.37, sd 0.69 [8]. For businesses, assign with normal distribution: mean 3.37, sd 0.69 [8].

- **Perceived Service Orientation ($PSO_{i,0}$):** Assign using normal distribution clamped between 1 and 5 based on [8]) Q10: For private individuals, assign using normal distribution with mean 3.22, sd 0.68 [8]. For businesses, assign with normal distribution: mean 3.18, sd 0.67 [8].
- **Social Norms ($SN_{i,0}$):** Assign using normal distribution clamped between 1 and 5 based on [8]) Q8: For private individuals, assign using normal distribution with mean 3.42, sd 1.06 [8]. For businesses, assign with normal distribution: mean 3.82, 1.02 [8].
- **Societal Norms ($StN_{i,0}$):** Assign using normal distribution clamped between 1 and 5 based on [8]) Q9: For private individuals, assign using normal distribution with mean 3.97, sd 1.01 [8]. For businesses, assign with normal distribution: mean 4.12, 0.98 [8].

- **Build Network:**
  - **Degree Assignment:** The graph $\mathcal{G}$ is initialized by assigning each agent i a target number of connections, k_i, drawn from a **lognormal** distribution (Mean 86.27, Std 64.99) from Dutch register research [12]. This distribution is chosen to ensure positive values and reflect the "long-tailed" nature of social contact data.
  - **Homophily:** Link formation prioritizes shared Occupation (o_i) and Sector (C_i) following [11]. The algorithm targets up to 80% of an agent's connections to be within the same group (i.e., Private individuals connect to other Private individuals; Businesses connect to others in the same sector).
  - **Sequential Construction:** Connections are unweighted and bidirectional. The network is built agent-by-agent as follows:
    1. For the current agent i, check their existing degree, $k_{current}$ (formed via bidirectional links from previously processed agents).
    2. If $k_{current} \geq k_i$, the agent has already met or exceeded their target; no new outgoing links are created, and existing excess links are retained.
    3. If $k_{current} < k_i$, the agent establishes $k_i - k_{current}$ new connections to reach their assigned target.

Phase 3: Simulation Loop (Timesteps $t = 1 \dots T$)

For each timestep t representing one fiscal year, the simulation proceeds through the following stages:

Stage 1: Agent Decision Making

Each agent i determines their declared income $X_{i,t}$ and evaded income $E_{i,t}$ based on a multi-step filter process. The filters are applied sequentially, reducing the pool of income the agent is willing to hide at each step.

- **Honest Agents:** If agent type τ_i is "honest", the agent declares full income, where Y_i is turnover or wage:
$$X_{i,t} = Y_i \quad \text{and} \quad E_{i,t} = 0 \tag{4}$$
- **Non-Honest Agents:** If agent type τ_i is "dishonest", the decision process involves four sequential filters:
  1. **Opportunity Filter (Maximum Concealable Income):** Calculate the maximum portion of income Φ_i that can be concealed based on occupation and specific SME parameters (such as cash intensity).
$$\Phi_i = \begin{cases} 0.10 & \text{if } o_i = \text{Private Individual (Employee)} \\ \phi_{SME}(R_{base}) & \text{if } o_i = \text{Business} \end{cases} \tag{5}$$
The maximum concealable income $M_{i,t}$ is:
$$M_{i,t} = Y_i \times \Phi_i \tag{6}$$

2. **Normative Filter (Tax Compliance Intention):** The agent's intrinsic willingness to comply is calculated based on psychometric traits. First, regressor values (Personal Norms PN, Social Norms SN, Societal Norms StN, Perceived Trust PT, Perceived Service Orientation PSO) are normalized from their original scale (1–5) to a standardized 0–1 range:

$$v_{norm} = \frac{v_{raw} - 1}{4} \tag{7}$$

Next, compute the Tax Compliance Intention ($TCI_{i,t}$) using regression coefficients derived from Gangl et al. [8]. The coefficients differ for Private individuals versus Business owners:

$$TCI_{i,t} = \beta_1 PN_i + \beta_2 SN_{i,t-1} + \beta_3 StN_{i,t-1} + \beta_4 PT_{i,t} + \beta_5 PSO_{i,t} \tag{8}$$

Where the coefficients are:

Parameter	**Private** ($o_i = \text{P}$)	**Business** ($o_i = \text{B}$)
β_1 (Personal Norms)	0.23	0.28
β_2 (Social Norms)	0.04	0.12
β_3 (Societal Norms)	0.11	0.09
β_4 (Perceived Trust)	0.13	0.14
β_5 (Service Orientation)	0.12	0.11

Sources: Norm coefficients from Table 3 (Block 4) [8]; PT and PSO coefficients from Mediation Analysis text (pg. 501) [8].

This intention acts as a constraint on evasion. The provisional willingness to evade after the normative filter, $W_{i,t}^{norm}$, is:

$$W_{i,t}^{norm} = M_{i,t} \times (1 - TCI_{i,t}) \tag{9}$$

3. **Social Influence Filter:** The agent adjusts their willingness based on the behavior of their network neighbors $\mathcal{N}_i$.

Let $\rho_{i,t}^{norm} = W_{i,t}^{norm}/M_{i,t}$ be the agent's current Fraud Opportunity Use Rate (FOUR) derived from the normative filter. We observe the FOUR values of the agent's neighbors to find the median:

$$\rho_{\mathcal{N}_i,t} = \text{median}(\{\rho_{j,t} \mid j \in \mathcal{N}_i, Y_j > 0\}) \tag{10}$$

The agent's rate is updated using a weighted average controlled by the social influence parameter $\omega \in [0, 1]$:

$$\rho_{i,t}^{soc} = \text{clip}\left((1-\omega)\rho_{i,t}^{norm} + \omega\rho_{\mathcal{N}_i,t},\ 0,\ 1\right) \tag{11}$$

The willingness to evade after social influence becomes:

$$W_{i,t}^{soc} = \rho_{i,t}^{soc} \times M_{i,t} \tag{12}$$

4. **Rational Choice Filter:** Finally, the agent evaluates the financial risk. This filter utilizes a heuristic based on the Allingham-Sandmo-Yitzhaki boundary condition [9], adjusted by risk aversion.

Let p_i be the subjective audit probability, f be the penalty rate, and r_i be the agent's risk aversion (on a scale of 0.5 to 5.0). The theoretical threshold for profitable evasion is:

$$\tau_{threshold} = \frac{1}{1+f} \tag{13}$$

If the audit probability $p_i \geq \tau_{threshold}$ (or if $p_i \geq 1$), the agent is deterred completely and $E_{i,t} = 0$.

Otherwise, the agent calculates a safety margin m_i and applies a risk dampening factor $D(r_i)$:

$$m_i = \frac{\tau_{threshold} - p_i}{\tau_{threshold}} \tag{14}$$

$$D(r_i) = 1.0 - \left(0.8 \times \frac{r_i - 0.5}{4.5}\right) \tag{15}$$

The final fraction of the willingness that is actually evaded, $\alpha_{i,t}$, is:

$$\alpha_{i,t} = \text{clip}(m_i \times D(r_i),\ 0,\ 1) \tag{16}$$

The final evaded income $E_{i,t}$ and declared income $X_{i,t}$ are:

$$E_{i,t} = \alpha_{i,t} \times W_{i,t}^{soc} \tag{17}$$

$$X_{i,t} = Y_i - E_{i,t} \tag{18}$$

Stage 2: Auditing and Enforcement

The tax authority selects agents for audit based on the chosen **Audit Strategy** and the defined **Audit Rate** [7, 9].

- Let $\mathcal{A}_t$ be the set of agents selected for audit.
- For each audited agent $i \in \mathcal{A}_t$:
  - **Detection:** The audit reveals the evasion $E_{i,t}$ (model assumes 100% audit success).
  - **Penalty:** The agent pays a tax/fine amount, calculated as in the utility function equation **9**: $f \cdot (t \cdot E_{i,t})$.
  - **Subjective Probability Update (Target/Bomb-Crater):** The agent updates their subjective audit probability p_i^{t+1}, with 50/50 likelihood of each of the following scenarios [9]:
    - *Target Effect:* $p_i^{t+1} = 1.0$ (Agent believes they are now watched).
    - *Bomb-Crater Effect:* $p_i^{t+1} = 0$ (Agent believes lightning won't strike twice).
  - **History Update (H_i):** For business agents (o_i = Business) who are audited, the specific type of audit recorded in their history is determined probabilistically. Based on the ratio of administrative audits to comprehensive book investigations ($0.18 : 0.07 \approx 2.57 : 1$) reported in [7], the audit type is assigned as follows:
    - *Administrative Audit ("administratief"):* Assigned with probability $P \approx 0.72$ (derived from $\frac{2.57}{2.57+1}$).
    - *Book Investigation ("boekenonderzoek"):* Assigned with probability $P \approx 0.28$.

    This classification directly impacts the agent's future Base Risk Score (R_{base}).
- For non-audited agents $i \notin \mathcal{A}_t$:
  - **Subjective Audit Probability Update**: drifts towards the category mean [9, 8]. For an individual with occupation o_i, the updated probability p^{t+1} adjusts by 0.1 standard deviations (σ) in the direction of the mean (μ):

$$p^{t+1} = \begin{cases} p^t + 2.2 \cdot \text{sign}(60.75 - p^t) & \text{if } o_i = \text{Private} \\ p^t + 2.3 \cdot \text{sign}(63.50 - p^t) & \text{if } o_i = \text{Business} \end{cases} \tag{19}$$

- **Trust and Service Orientation Update (PT, PSO):** The evolution of Perceived Trust (PT) and Perceived Service Orientation (PSO) is governed by agent-authority interactions and specific service channels. To ensure validity for Equation **7**, all updated values are strictly clamped to the interval $[1, 5]$.

  1. **Trust (PT) Update Rules:** Trust updates occur solely based on audit outcomes:
     - **Audited and Compliant:** If agent i is audited and found compliant, trust increases to reflect the correct validation of innocence.

$$PT_{i,t+1} = \min\left(5, PT_{i,t} + 0.5 \cdot \sigma_{trust}\right)$$

- **Audited and Non-Compliant:** If agent i is found non-compliant, there is a probability $p_{unfair} = 0.30$ that the agent perceives the audit as flawed or unfair. This is arbitrary and needs to be refined through further research!
  - If perceived unfair: $PT_{i,t+1} = \max(1, PT_{i,t} - 1.0 \cdot \sigma_{trust})$.
  - Otherwise: $PT_{i,t+1} = PT_{i,t}$ (no change).
- **Not Audited:** $PT_{i,t+1} = PT_{i,t}$.

2. **Service Orientation (PSO) Update Rules:** PSO updates differ by agent type, incorporating telephone contact, webcare interaction, and specific assistance campaigns.
   - **Private Individuals:**
     - *Telephone Channel:* Agents interact via phone with probability $P_{phone} = \frac{5{,}400{,}000}{10{,}250{,}000} \approx 0.527$, based on total calls from private individuals handled as per the Jaarreportage versus the labor force size (ages 15 to 74) [7, 2].
       - With probability 0.80 (satisfaction ≥ 3 [7]):
       $$PSO_{i,t+1} = \min(5, PSO_{i,t} + 0.5 \cdot \sigma_{PSO})$$
       - With probability 0.20:
       $$PSO_{i,t+1} = \max(1, PSO_{i,t} - 1.0 \cdot \sigma_{PSO})$$
     - *Webcare Channel:* All agents are assumed to interact with web services. A satisfaction score S is sampled from $\mathcal{N}(\mu = 3.2, \sigma = 1)$ [7].
       - If $S > 3$: $PSO_{i,t+1} = \min(5, PSO_{i,t} + 0.5 \cdot \sigma_{PSO})$.
       - Else: $PSO_{i,t+1} = \max(1, PSO_{i,t} - 0.5 \cdot \sigma_{PSO})$.
     - *HuBA Campaign:* With probability $P_{HuBA} = \frac{41{,}000}{10{,}250{,}000} \approx 0.004$, representing citizens receiving special filing assistance [7], the agent's perception is maximized:
     $$PSO_{i,t+1} = 5$$
   - **Business Agents:**
     - *Telephone Channel:* Agents interact via phone with probability $P_{phone} = \frac{2{,}200{,}000}{2{,}392{,}455} \approx 0.92$, based on business calls reported in Jaarreportage versus the total number of SMEs in the Netherlands [7, 1].
       - With probability 0.80 (satisfaction ≥ 3):
       $$PSO_{i,t+1} = \min(5, PSO_{i,t} + 1.0 \cdot \sigma_{PSO})$$
       - With probability 0.20:
       $$PSO_{i,t+1} = \max(1, PSO_{i,t} - 1.0 \cdot \sigma_{PSO})$$
     - *Webcare Channel:* We assume all agents interact with web services. A satisfaction score S is sampled from $\mathcal{N}(\mu = 3.5, \sigma = 1)$ [7].
       - If $S > 3$: $PSO_{i,t+1} = \min(5, PSO_{i,t} + 0.5 \cdot \sigma_{PSO})$.
       - Else: $PSO_{i,t+1} = \max(1, PSO_{i,t} - 0.5 \cdot \sigma_{PSO})$.

Stage 3: Information Spread and Norm Updating

Information about audits and attitudes spreads through the network, updating beliefs and norms for the next timestep $t + 1$ [9].

- **Meetings and Interaction:** The social network is defined by a fixed symmetric adjacency matrix A (where $A_{ij} = 1$ if linked). In each period t, a random binary (50/50) matrix I_t is drawn. Agents i and j meet only if they are linked AND selected by this matrix (i.e., $A_{ij}I_{ij,t} = 1$) [9].
- **Belief Update (Subjective Audit Probability):** Each agent's subjective probability of audit shifts towards the median subjective probability of ALL its neighbors who it met:
$$p_i^{t+1} = (1 - \omega)p_i^{t+1} + \omega * \text{median}(\{p_{j,t} \mid j \in \mathcal{N}_i \text{ and } A_{ij}I_{ij} = 1) \tag{20}$$
Where ω is the previously defined social influence coefficient.

- **Social Norm Update (SN):** Social norms evolve based on the aggregate behavior observed among each agent's set of **neighbors with whom it interacts** [9]. In each round t, an agent i calculates a raw social compliance score, $S_{i,t}^{raw}$, by summing the contributions of every audited and non-audited neighbor j they interact with (where $j \in \mathcal{A}_t$ and $A_{ij}I_{ij} = 1$):

$$S_{i,t}^{raw} = \sum_{j \in \mathcal{N}_{i,t} \text{ and } j \in \mathcal{A}_t \text{ and } A_{ij}I_{ij}=1} c_j, \quad \text{where } c_j = \begin{cases} 1 & \text{if } E_{j,t} = 0 \quad \text{(Full Compliance)} \\ -\frac{E_{j,t}}{Y_j} & \text{if } E_{j,t} > 0 \quad \text{(Partial/Non-Compliance)} \end{cases} \tag{21}$$

Here, E_j is the evaded income of neighbor j. The raw scores are normalized by dividing by the number of neighbors.

The Social Norm value SN_i is then adjusted by 0.5 of the population standard deviation (σ), scaled by this normalized score, and strictly clamped between 1 and 5:

$$SN_{i,t+1} = \max\left(1, \min\left(5, SN_{i,t} + \hat{S}_{i,t} \times \begin{cases} 0.53 & \text{if } o_i = \text{Private} \quad (0.5 \times 1.06) \\ 0.51 & \text{if } o_i = \text{Business} \quad (0.5 \times 1.02) \end{cases}\right)\right) \tag{22}$$

Note: the social influence coefficient ω is excluded because as per the definition in [8] this measures the agent's subjective perception of peer behavior, not their own susceptibility to being influenced by this behaviour [8]. That susceptibility is reflected in equations **7** and **11**.

- **Societal Norm Update (StN):** Societal norms shift based on aggregate statistics (e.g., total tax gap). In each round, one singular societal compliance score is computed:

$$St_t^{raw} = \sum_{k \in \mathcal{G}} c_k, \quad \text{where } c_k = \begin{cases} 1 & \text{if } E_{k,t} = 0 \\ -\frac{E_{k,t}}{Y_k} & \text{if } E_{k,t} > 0 \end{cases} \tag{23}$$

The raw score is normalized by division with the total number of agents.

The Societal Norm value StN_i is then adjusted by 0.1 of the population standard deviation (σ), scaled by this normalized score, and clamped:

$$StN_{i,t+1} = \max\left(1, \min\left(5, StN_{i,t} + \hat{St}_t \times \begin{cases} 0.101 & \text{if } o_i = \text{Private} \quad (0.1 \times 1.01) \\ 0.098 & \text{if } o_i = \text{Business} \quad (0.1 \times 0.98) \end{cases}\right)\right) \tag{24}$$

As with social norms, ω is excluded [8].

Stage 4: Metrics Calculated at Simulation Step

Metric	Description / Calculation
Tax Gap	$\sum$(agent evaded income $\times$ tax_rate) for all agents. The raw amount of tax money lost to evasion in this step.
Compliance Rate	$\frac{\text{count(compliant\_agents)}}{\text{total\_agents}}$. The percentage of agents who declared 100% of their income.
Total Taxes	$\sum$(agent declared income $\times$ tax_rate) for all agents. The total tax revenue collected.
Audits	Count of agents selected for audit in this step.
Avg Declaration Ratio	Average of $\left(\frac{\text{Declared Income}}{\text{True Income}}\right)$ across all agents. Capped at 1.0 (no credit for over-declaring).
Tax Morale	Weighted average of agent traits: $0.18 \cdot \text{Social} + 0.23 \cdot \text{Societal} + 0.27 \cdot \text{PSO} + 0.32 \cdot \text{Trust}$. Normalized to a 0–100 scale.
Avg FOUR	**F**raud **O**pportunity **U**se-**R**ate: Average evasion rate among *only* the agents who (a) are not "honest" type and (b) had an opportunity to evade, calculated as ratio between concealed amount and maximum concealable amount.
Avg PSO	Average `perceived_service_orientation` trait across all agents.
MGTR	Mean Gross Tax Rate: $\frac{\text{Total Tax Revenue+Penalties Collected}}{\text{Total True Income}}$. The effective tax burden on the population.
Penalties	Sum of all penalties assessed from audits in this step, in raw money terms.

Phase 4: Metrics Calculated/Displayed at End

These are aggregated after all simulation runs complete, and displayed on the Results page.

Note on Aggregation:

All "Total" or "Final" metrics are the **average per run** (e.g., if you run 5 simulations, it shows the average result of a single simulation).

Display Name	Calculation Logic
Total Tax Revenue	Average sum of `Total Taxes` collected over the full duration, averaged across runs.
Total Tax Gap	Average sum of `Tax Gap` accumulated over the full duration, averaged across runs.
Final Compliance	The `Compliance Rate` at the very last step (averaged across runs).
Final FOUR	The `Avg FOUR` at the very last step (averaged across runs).
Tax Morale	The `Tax Morale` at the very last step (averaged across runs).
Final MGTR	The `MGTR` at the very last step (averaged across runs).
Audits Performed	**Sum** of all audits across all steps (averaged across runs).
Correction Yield	**Sum** of all penalties collected across all steps (averaged across runs).
Initial Compliance	The `Compliance Rate` at step 0 (averaged across runs).
Max Compliance	The highest single-step `Compliance Rate` observed during a run (averaged across runs).
Final Declaration Ratio	The `Avg Declaration Ratio` at the very last step (averaged across runs).
Collection Efficiency	$\frac{\text{Total Tax Revenue}}{\text{Total Tax Revenue}+\text{Total Tax Gap}}$. Represents the % of potential revenue captured (averaged across runs).

References

[1] StatLine - Bedrijven; bedrijfstak.

[2] StatLine - Labour participation; key figures.

[3] StatLine - Self-employed persons; income, wealth, characteristics.

[4] StatLine - Welfare of persons; key figures, 2011-2023.

[5] Micro-, small- and medium-sized enterprises: definition and scope | EUR-Lex, January 2005. Doc ID: n26026 Doc Sector: other Doc Title: Micro-, small- and medium-sized enterprises: definition and scope Doc Type: other Usr_lan: en.

[6] Amanda L. Andrei, Kevin Comer, and Matthew Koehler. An agent-based model of network effects on tax compliance and evasion. *Journal of Economic Psychology*, 40:119–133, February 2014.

[7] Ministerie van Financiën. Jaarrapportage 2024 Belastingdienst - Rapport - Rijksoverheid.nl, May 2025. Last Modified: 2025-05-27T14:25.

[8] Katharina Gangl, Stephan Muehlbacher, Manon de Groot, Sjoerd Goslinga, Eva Hofmann, Christoph Kogler, Gerrit Antonides, and Erich Kirchler. "How can I help you?" Perceived Service Orientation of Tax Authorities and Tax Compliance. *FinanzArchiv / Public Finance Analysis*, 69(4):487–510, 2013. Publisher: Mohr Siebeck GmbH & Co. KG.

[9] Nigar Hashimzade, Gareth Myles, Frank Page, and Matthew Rablen. The use of agent-based modelling to investigate tax compliance. *Economics of Governance*, 16:143–164, May 2015.

[10] Statistics Netherlands. Business Survey Netherlands (COEN). Last Modified: 14-04-2025T07:26:47.

[11] Jose A. Noguera, Toni Llacer, Miguel Quesada, and Eduardo Tapia. An Agent-Based Model of Tax Compliance: An Application to the Spanish Case. *Advances in Complex Systems*, 16:33 pages, August 2013.

[12] Nicolás Soler, Eelke Heemskerk, and Yuliia Kazmina. *Contacts in contexts: A population-scale social network approach to the study of close intergroup social ties.* February 2024.