

# Taming the Bullwhip Effect via FHE

## Blind Demand Aggregation & Shapley Incentives on FluidCluster 2.0

ZLT#13 Sandbox Sandbox Environment — DL 150/2019 Compliance

FluidCluster & Ecompensa Sovereign Architecture

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# The Target Problem: The Bullwhip Effect

## The Information Asymmetry Blindspot

Variance in demand orders amplifies upstream across multi-tier supply networks, generating massive storage overheads, stockouts, and capital traps.

- **Why It Occurs Today:** Upstream tiers lack real-time visibility into baseline consumer demand parameters due to competitive hoarding.
- **The Coordination Deadlock:** Suppliers refuse to show raw inventories, true backlogs, or run rates, fearing margin extraction and poaching.
- **The Structural Bottleneck:** Classic inventory aggregation requires centralizing data, exposing enterprise trade secrets.

# The Architecture Solution: The Blind Demand Pipeline

## True Inventory Visibility without Data Disclosure

FluidCluster 2.0 compiles multi-tier consumer parameters directly inside encrypted execution layers using homomorphic mathematics.

- **Edge Ingestion:** Edge SDKs run locally on business ERP lines, converting real-time sales velocity metrics into FHE variables.
- **Blind Global Summation:** Upstream manufacturers process the aggregate downstream requirement vector completely in ciphertext:

$$\mathcal{E}(D_{global}) = \sum_{i=1}^n \mathcal{E}(d_i)$$

- Zero raw numbers leave individual corporate endpoints.

## Overcoming Co-opetition Stagnation

Simply providing a private tunnel is insufficient. Businesses must be cryptographically motivated to feed accurate data trends early into the loop.

- **The Cooperative Game:** We model the supply chain network as a grand coalition  $N$ . The value function  $v(S)$  measures the volatility reduction savings achieved by an optimized subset of nodes  $S$ .
- **Truthful Revelation Strategy:** To guarantee that nodes submit true demand forecasts instead of bloated, defensive estimates, the platform enforces an algorithmic incentive scheme.
- **The Instrument:** Real-time allocation of **\*\*Shapley Tokens\*\***, assigning systemic value according to a participant's precise marginal contribution.

# The Incentive Core: Shapley Contribution Values

## Algorithmic Fairness under Cryptographic Conditions

The platform distributes optimization payouts or priority manufacturing queue rights using a blind computation of the classic Shapley formulation.

$$\phi_i(v) = \sum_{S \subseteq N \setminus \{i\}} \frac{|S|!(|N| - |S| - 1)!}{|N|!} [v(S \cup \{i\}) - v(S)]$$

- **Evaluating**  $v(S \cup \{i\}) - v(S)$ : An fhEVM smart contract assesses the reduction in variance achieved when Node  $i$ 's input data joins the cluster.
- **Blind Fairness**: The marginal calculation operates entirely inside the cipher domain. The system mints **\*\*Shapley Tokens\*\*** to Node  $i$  proportional to its value, without revealing its absolute inventory volume.

# System Integration Matrix

| Workflow Element      | Cryptographic Driver                  | Systemic Outcome                                                                |
|-----------------------|---------------------------------------|---------------------------------------------------------------------------------|
| Data Ingestion        | Local Edge Client Core                | Formats raw ERP logs to match uniform cryptographic tables locally.             |
| Signal Processing     | Zama fhEVM + TFHE Line                | Runs variances, matrix adjustments, and global demand sums blindly.             |
| Hardware Acceleration | Photonic PIC Arrays [fluidcluster.pt] | Bypasses silicon compute barriers via light-speed ciphertext matrix operations. |
| Incentive Clearance   | Token Minting Engine                  | Issues sovereign Shapley utility credits to reward data contribution.           |

# Macroeconomic and Commercial Payoffs

## Micro Impacts for Nodes

- Up to **40% reduction** in safety stock holding costs.
- Total mitigation of phantom orders.
- Strategic asset allocation stability.

## Macro Network Value

- Stabilized wholesale supply chain infrastructure across 1,000,000 entities.
- Compliant under Portuguese Decree-Law no. 150/2019 validation frameworks.
- High-fidelity operational capacity utilization.

## Moving from Sandbox ZLT#13 to Global Enterprise Scale

### Milestones Set

- 1 Establish edge data parsing layers.
- 2 Run Shapley validation tests in sandbox environments.
- 3 Onboard institutional consortium supply chains.

### Inquiries & Developer Access:

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*Ecompensa 2.0: Orchestrating global industrial efficiency under absolute computational blindness.*