Game-Theoretic Decision Rights Allocation for Cross-Enterprise Data Sharing Under the Federated Learning FATE Framework Under the Data Legal Context:

An Automotive Supply Chain Study

Junyuan Wan
Department of Law, Dong-A University, South Korea & Hubei Provincial Automobile Industry Intellectual Property Research Institute, China

Ping Guo
School of Law and Public Administration, Yibin University, China

Shiqi Feng
Corporate Legal Affairs Department, Shandong Gold Group Penglai Mining Co., Ltd., China

Zichen Liu
https://orcid.org/0009-0000-3028-1518
School of Law, Henan University of Urban Construction, China & Intellectual Property Convergence Department, Gyeongsang National University, China
Received: August 31st, 2025 | **Accepted:** December 29th, 2025

ABSTRACT

In modern automotive supply chains, enterprises such as manufacturers, component suppliers, and logistics providers are tightly interconnected yet reluctant to share operational data due to privacy, competitive, and regulatory concerns. While federated learning (FL) offers a technical pathway for collaborative model training without exposing raw data, most existing frameworks neglect the governance challenge of allocating decision rights among partners with diverse data quality, volume, and computational resources. This study proposes a game-theoretic decision rights allocation mechanism integrated into the FATE federated learning platform, designed to ensure fairness, efficiency, and stability in cross-enterprise data sharing. The method models each participant's contribution through a payoff function incorporating data utility, timeliness, and cost, and determines decision influence by solving for a cooperative Nash equilibrium under privacy constraints.

KEYWORDS

Federated Learning, FATE Framework, Game Theory, Automotive Supply Chain, Decision Rights Allocation, Data Legal

INTRODUCTION

In recent years, the automotive supply chain has undergone a profound transformation driven by globalization, tighter delivery schedules, and the rapid adoption of digital technologies. Collaboration across enterprises—once limited to contractual agreements and manual coordination—has increasingly

DOI: 10.4018/JOEUC.399145

shifted toward data-driven integration. The ability to share operational data securely and effectively is now recognized as a decisive factor in improving demand forecasting, optimizing logistics, and meeting environmental targets (Fu et al., 2023; Nguyen et al., 2021; Pham et al., 2021). Nevertheless, in practice, cross-enterprise data sharing remains fraught with concerns over competitive advantage, data privacy, and control over decision-making processes.

Federated learning (FL) has emerged as a compelling paradigm for enabling multi-party collaboration without centralized data aggregation (Farahani & Monsefi, 2023; Hu et al., 2023; Wang et al., 2022; Zheng et al., 2023; Zheng et al., 2025). Among various frameworks, WeBank's Federated Artificial Intelligence Technology Enabler (FATE) platform offers mature tooling for both vertical and horizontal FL, secure multi-party computation (SMPC), and a flexible architecture suitable for heterogeneous environments. However, while FATE ensures privacy protection, it leaves open the question of how decision-making power should be distributed among participating enterprises, particularly when their contributions to the shared model vary. In supply chain contexts—especially in the automotive sector where suppliers, manufacturers, and logistics providers form intricate networks—imbalanced decision rights can quickly erode trust and undermine long-term cooperation (Hameed & Mohamad, 2023; Lim et al., 2021; Zhang et al., 2021).

Existing research on FL in supply chains has largely concentrated on algorithmic performance—improving convergence rates, handling data heterogeneity, or optimizing routing problems (Tariq et al., 2025; Zeng et al., 2022). These works have provided valuable advances but tend to overlook the governance dimension: Who gets to influence model updates, and to what extent (Wan et al., 2023)? Without a principled mechanism for allocating decision rights, participants contributing high-quality or high-volume data may feel underrepresented, while smaller contributors may fear being marginalized. Attempts to address this through heuristic weighting or static contribution metrics fall short when enterprise behaviors evolve or when the collaboration spans multiple objectives, such as cost, fairness, and sustainability.

The present study seeks to fill this gap by integrating cooperative game theory into the FATE framework, yielding what we term an FL framework for game-theoretic decision rights allocation (Fed-GDR). This approach explicitly models participants as rational agents with varying data value and strategic interests, formulates payoff functions that incorporate both predictive and operational benefits (Pokhrel & Choi, 2020), and computes equilibrium allocations that balance fairness with efficiency. Within this framework, decision rights are neither arbitrarily assigned nor solely determined by data volume—they emerge from a stable cooperative game solution, ensuring both fairness and coalition stability (He et al., 2021). The automotive supply chain is adopted as the primary study domain, as it offers a rich, high-stakes environment for testing the interplay between privacy-preserving collaboration and governance.

The proposed method addresses three central challenges. First, ensuring privacy and data security when sensitive operational data is distributed across legally independent entities. Second, designing a decision rights allocation mechanism that remains equitable under dynamic participation and heterogeneous contributions. Third, embedding this mechanism into a practical FL platform without incurring prohibitive computational overhead. Our solution combines FATE's SMPC protocols with a Shapley-value-inspired allocation model, augmented to support multi-objective optimization involving cost, emissions, and fairness constraints.

This paper makes four main contributions. First, it introduces a novel decision rights allocation mechanism grounded in cooperative game theory and fully integrated with the FATE framework. Second, it demonstrates, through extensive experiments on diverse datasets, that the method improves predictive accuracy, reduces operational costs, and lowers emissions while enhancing fairness and stability compared to state-of-the-art baselines. Third, it proposes a unified evaluation protocol for cross-enterprise FL scenarios that jointly assesses optimization effectiveness, equity, and coalition stability. Fourth, it provides the first application of such a framework to an automotive supply chain context, highlighting both technical feasibility and potential industrial impact.