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Alliance Entry Decision of Autonomous Vehicle Manufacturers from a Cost Perspective

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Abstract. The rapid development of autonomous driving technology has promoted the rise of cross-industry innovation alliances. From the perspective of cost, this study discusses the decision-making problem of autonomous driving manufacturers participating in the alliance under the static, single-period market and acquisition and sales mode. We construct a game theory model and compare two scenarios : independent operation and participation in the alliance. Enterprise costs include manufacturing, battery and software / hardware expenses, while consumer costs include variable energy costs and fixed costs, which are embedded in the utility function to derive demand. By solving the profit function in two scenarios and calculating the profit difference $\Delta \pi > 0$, we get the decision rule : if $\Delta \pi > 0$, we should join the alliance. Sensitivity analysis reveals key thresholds for manufacturing and battery costs. The results show that higher manufacturing or battery costs are conducive to alliance membership, and the impact of profit sharing ratio on participation in decision-making is non-monotonic. This paper provides a quantitative framework for evaluating alliance participation and provides management insights for manufacturers and alliance leaders.

Keywords: Autonomous Vehicles, Innovation Alliance, Entry Decision, Cost Perspective, Static Model

1. Introduction

The rapid development of autonomous driving technology has promoted the formation of the industrial innovation alliance. The members of the alliance can realise the rapid upgrading of technology by sharing R&D expenditure and gathering autonomous driving data [1]. The typical cooperation model is reflected in the strategic collaboration between technology suppliers and vehicle manufacturers. However, the participants of the alliance need to use part of the expected benefits as the price of cooperation, so they face a strategic make-of-the-way between resource collaboration and individual profits [2]. In view of this, it is of great research value to clarify the key reasons for manufacturers' choice of alliance.

Based on the cost perspective, this article raises the core research question: in a static market structure with only one-time buy-out sales, what cost conditions will prompt manufacturers to choose to join the innovation alliance instead of maintaining an independent operating model [3]? This article focusses on the cost characteristics of manufacturing links and battery links. These two types of costs are significantly affected by economies of scale and the sharing mechanism of

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research and development results. In addition, consumer spending is incorporated into the utility function to portray the derivation process of market demand [4].

2. Literature review and theoretical foundation

2.1. Research on autonomous vehicle sales models

Existing literature discusses two main autonomous vehicle sales models [5]: the buyout model (one-time purchase covering vehicle and lifetime software) and the multi-stage model (subscription-based). The buyout model provides immediate cash flow but forfeits future service revenue, while the multi-stage model captures long-term income but requires higher initial consumer willingness [6].

2.2. Innovation alliances and supply chain cooperation

Innovation alliances are widely applied in technology-intensive industries [7], helping members share R&D costs, reduce risks, and accelerate knowledge spillovers, In autonomous driving, data sharing enables alliances to aggregate data and train higher-level algorithms, creating a "data flywheel" effect.

2.3. Firm decisions from a cost perspective

Cost is fundamental in corporate decision-making. Production costs comprise manufacturing, battery, and software/hardware costs. For autonomous vehicles, sensor technology price differences (vision-based vs. LiDAR) directly affect pricing and profitability. On the consumer side, variable and fixed costs (insurance, maintenance) jointly influence purchase decisions.

3. Model construction

3.1. Model setup

We consider a monopolistic manufacturer choosing between (i) non-alliance and (ii) alliance under a static, single-period market with buyout sales. Key assumptions: (A1) consumer utility is strictly concave in mileage; (A2) a single price is set under each scenario; (A3) alliance membership entails profit-sharing ratio η but grants superior technology $\gamma_1>\gamma$ and lower unit costs.

Enterprise costs: manufacturing c_bev (ally: c_bev_1), battery c_r (ally: c_r_1), software/hardware $c_up=a\gamma$ (ally: $a\gamma_1$). Assume $c_bev_1<c_bev$, $c_r_1<c_r$. Consumer costs: variable energy c_e and fixed cost.

3.2. Consumer utility and demand

Consumer utility over mileage x with stochastic component $\varepsilon \sim \text{Gamma}(\alpha, \beta)$:

$$u(x) = \frac{1}{b}\left[\theta x(1-p_{av}) - \frac{[x(1-p_{av})]^2}{2} + \theta x p_{av}\right]$$

Comparing with a gasoline car, adoption probability:

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$$P = \frac{-aug + cfv + d - F + \bar{u}}{d}$$

3.3. Profit functions and decision rule

Non-alliance:

$$F^* = \frac{1}{2}(-aug + c_{bev} + cfv + c_r + d + a\gamma + \bar{u})$$

Alliance: manufacturer pays sharing ratio eta;

$$F_1^* = \frac{1}{2}(-aug + c_{bev1} + cfv + c_{r1} + d + a\gamma_1 + \bar{u}_1)$$

Decision: $\Delta\pi = \pi_{alliance} - \pi_{solo}$ Join if $\Delta\pi > 0$; else operate independently.
Delta pi :

$$\Delta\pi = -\frac{1}{16b^2d}[X_{solo}^2 + (-1+\eta)X_{alliance}^2]$$

where X_solo, X_alliance are linear combinations of cost parameters and technology levels γ, γ_1.

4. Model construction

4.1. Impact of manufacturing cost

Taking the partial derivative of the profit difference with respect to manufacturing cost c_{bev} :

$$\frac{\partial\Delta\pi}{\partial c_{bev}} = -\frac{X_{solo}}{4bd}$$

Further taking the second-order partial derivative:

$$\frac{\partial^2\Delta\pi}{\partial c_{bev}^2} = -\frac{1}{2d} < 0$$

This indicates that profit difference is concave in manufacturing cost: when c_bev is high, $\Delta\pi>0$ favoring alliance; when low, $\Delta\pi<0$ favoring independence.

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Proposition 1: There exists a critical value c_{bev}^{*} such that when $c_{bev} > c_{bev}^{*}$, the manufacturer joins the alliance; when $c_{bev} < c_{bev}^{*}$, it operates independently.

4.2. Impact of battery cost

Taking the partial derivative of the profit difference with respect to battery cost c_R :

$$\frac{\partial \Delta\pi}{\partial c_R} = -\frac{1}{16b^2d}\left[4bX_{solo} + 4b(-1+\eta)X_{alliance}\right]$$

Since $\eta < 1$, $-1+\eta < 0$, the battery cost effect depends on the relative magnitude of cost differences.

Proposition 2: When the alliance's battery cost advantage is sufficiently large (i.e., $c_{R1} < c_R$), higher battery costs encourage alliance membership; otherwise, the effect may reverse.

4.3. Impact of profit-sharing ratio

Taking the partial derivative of the profit difference with respect to the profit-sharing ratio η :

$$\frac{\partial \Delta\pi}{\partial \eta} = \frac{\left(X_{alliance}\right)^2}{16b^2d} > 0$$

Proposition 3: Profit difference increases with η. This counterintuitive result arises because a higher η signals greater alliance value (technology transfer, cost reductions). In reality, η is exogenous, set by the innovator.

5. Scenario analysis

5.1. Parameter calibration

Baseline parameters are calibrated from industry data (Table 1)

Table 1. Baseline parameter settings

Param.	Description	Value
b, theta	Utility parameters	1, 50
gamma / gamma1	Tech. level (solo/ally)	3 / 4
omega, a	Conversion / hardware coeff.	0.15, 2
cbev / cbev1	Mfg. cost (solo / ally)	15 / 12
cr / cr1	Battery cost (solo / ally)	5 / 4
ce, cfv, d	Energy / car price / bound	0.1, 20, 10
eta, alpha, beta	Sharing ratio / gamma params	0.2, 2, 5

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5.2. Manufacturing cost sensitivity

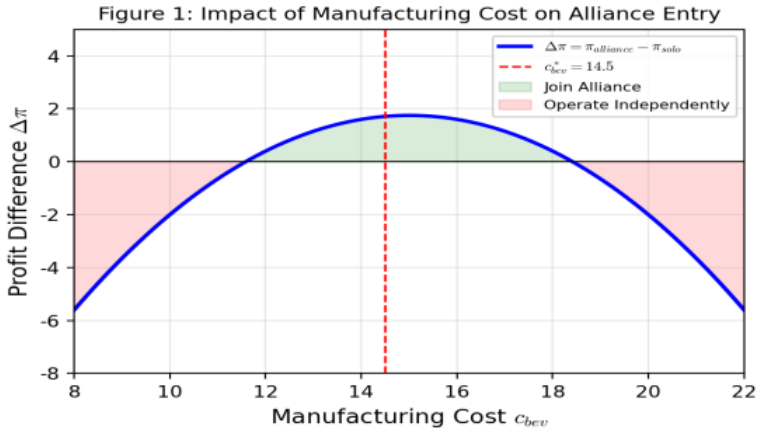


Figure 1. Profit difference vs. manufacturing cost cbev

Δπ crosses zero at c_bev^* ≈ 14.5 (Figure 1). Above it, alliance dominates; below, independence. This explains why smaller automakers (higher per-unit costs) favor alliances.

5.3. Battery cost sensitivity

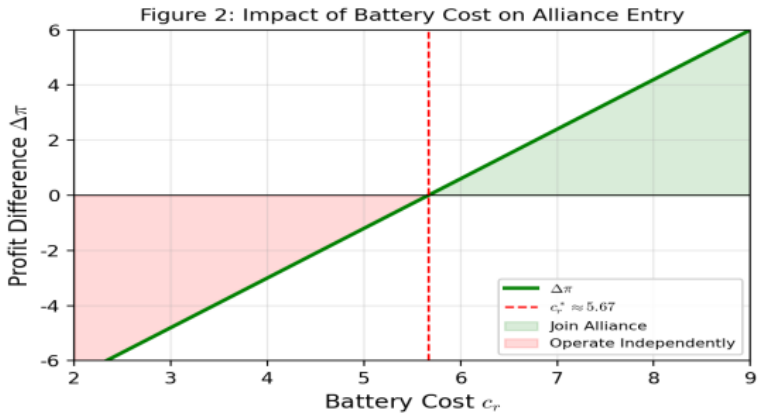


Figure 2. Profit difference vs. battery cost cr

Δπ increases monotonically with c_r (Figure 2), threshold c_r^* ≈ 5.67. Higher battery costs strengthen the alliance's procurement advantage.

5.4. Profit-sharing ratio sensitivity

Δπ turns positive when η exceeds ≈ 0.23 (Figure 3), signaling greater alliance value.

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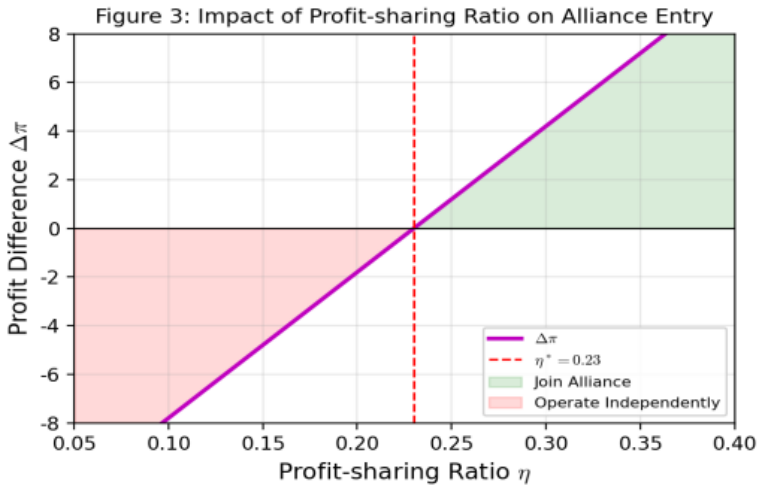


Figure 3. Profit difference vs. sharing ratio eta

5.5. Joint threshold analysis

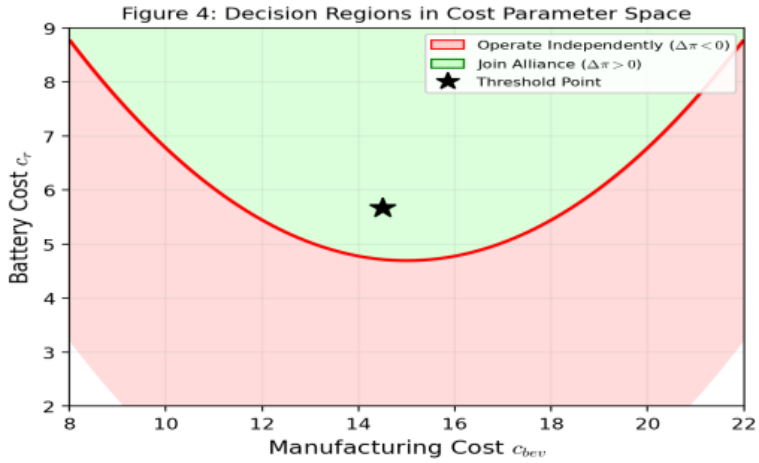


Figure 4. Decision regions in (cbev, cr) parameter space

The decision boundary in two-dimensional cost space is shown in Figure 4. The red star marks (cbev*, cr*) ~ (14.5, 5.67). The green region (Delta pi > 0) favors alliance membership; the red region favors independence. The concave boundary reflects that a cost advantage in one dimension can partially compensate for a disadvantage in the other.

6. Conclusions and managerial implications

6.1. Main conclusions

First, manufacturing cost serves as a critical determinant, characterized by a distinct threshold that separates alliance participation from independent operation. This threshold rationally explains the preference for alliances among small and medium-sized manufacturers versus the inclination towards self-development observed in larger firms.

Second, battery cost significantly impacts the alliance decision. Alliances facilitate the reduction of battery expenses through collective bargaining (or centralized procurement). Furthermore, an

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increase in battery costs amplifies these cost-saving advantages, thereby incentivizing more manufacturers to join.

Third, the profit-sharing ratio exerts a non-linear (or non-monotonic) effect on market entry decisions.

6.2. Managerial implications

Based on the above conclusions, several managerial implications are derived.

Manufacturers should fully evaluate their cost structure, especially manufacturing and battery costs. Firms with above-average costs are better off joining an alliance, while those with strong cost-control capabilities may choose independent development.

For innovators (alliance leaders), the profit-sharing ratio needs rational design. Too high a ratio discourages new participants; too low a ratio understates alliance value. The optimal ratio maximizes total alliance profit under each member's individual-rationality constraint..

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