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The proportion of state-owned shares and capacity sharing with constraints and prices in a mixed oligopoly

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ABSTRACT

This study constructs an oligopoly model composed of mixed-ownership and private enterprises, examining the equilibrium results of three cases: when two enterprises compete with sufficient capacity (Model AA), insufficient capacity and overcapacity coexist without sharing (Model IA), and sharing (Model IS). This study also explores the effects of the proportion of state-owned shares, capacity constraints, and capacity prices. The realisation conditions and impacts of capacity sharing are further analysed. The results show that the efficiency of state-owned capital affects the effects of state-owned shares on the equilibrium results. An optimal capacity price exists for the capacity provider (private enterprise). Capacity sharing can effectively allocate resources and increase profits; however, consumers and society do not necessarily benefit from it. Full privatisation and the highest proportion of state-owned shares may be the best choice for the government under certain conditions. The government can intervene in enterprises' capacity decision-making through subsidies to promote social welfare and realise capacity sharing simultaneously. Moreover, the government subsidises different enterprises when the proportions of state-owned shares and capacity prices are within different ranges.

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1. Introduction

In the modern economy, state-owned and private enterprises are no longer independent but combined to a certain extent. Mixed-ownership enterprises play an essential role in many industries (Du & Wang, 2020; Lo et al., 2022; Wang et al., 2021). Simultaneously, there has been continuous progress in modern information technology, especially with the emergence of the digital economy. In 2020, the added value

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of the Chinese digital economy's core industries accounted for 7.8% of its gross domestic product (GDP). The digital economy can reduce transaction fees and production costs, enabling capacity sharing (Henni et al., 2021; Xiao et al., 2022). In transportation, energy, manufacturing, and other industries, an increasing number of enterprises actively promote capacity sharing to alleviate capacity imbalances and effectively allocate capacity resources in space and time (Ma & Xie, 2022; Melo et al., 2019; Shao, 2021). Taking China as an example, in 2020, the transaction scale of the sharing economy market was approximately 3.377 trillion yuan, a year-on-year increase of 2.9%. Life services, capacity, knowledge, and skills rank among the top three categories in the sharing economy's market size. There were 830 million participants, with a year-on-year increase of approximately 7.7%. The advantages of shared manufacturing have been highlighted during the extraordinary period of the COVID-19 pandemic, and leading enterprises in the industry have continued to increase resource opening and sharing (Yu et al., 2021). Many mixed-ownership economies and enterprises exist in the capacity sharing market. For example, as an essential part of China's capacity sharing market, its steel industry is composed of state-owned, private, and mixed-ownership enterprises, of which mixed-ownership enterprises are the mainstay. In 2019, the automakers' Brilliance Group and Lifan Group shared a car production capacity of 18,000 vehicles, providing an example of cooperation between mixed ownership and private enterprises in the automobile industry. What effects does the proportion of state-owned shares have on the capacity sharing and equilibrium results? What is the optimal proportion of state-owned shares? In the case of mixed ownership, what effects does capacity sharing have on enterprises, consumers, and society? Is capacity sharing necessarily positive? What role does the government play in these activities? How does the government intervene to promote social welfare? This study constructs a duopoly model consisting of a mixed-ownership enterprise and a private enterprise, analysing the impact of the proportion of state-owned shares and capacity sharing under different scenarios to answer these questions. The equilibrium results show that the proportion of state-owned shares and the efficiency of state-owned capital have complex effects on market participants. Capacity constraints and price affect the equilibrium results, and capacity sharing can effectively allocate resources to improve enterprise profits. The optimal proportion of state-owned shares in the three cases differs, and government subsidies affect enterprises' capacity decisions.

The contributions of this study are as follows. First, although the literature combines state-owned shares with capacity selection (Bettini & Oliveira, 2016; Li et al., 2019; Noruzoliaee et al., 2015), there are still relatively few analyses of the impact of the state-owned share proportion on capacity sharing. This study incorporates the proportion of state-owned shares into the capacity sharing model, deepening research on the implementation and impact of mixed ownership and capacity sharing. Second, the existing models largely ignore the impact of different types of capital on costs. It is assumed that the efficiencies of state-owned and private enterprises are the same or that state-owned shares have no impact on costs (Lee & Park, 2021). In reality, the impact of different property rights on costs is an important factor affecting the choice of mixed ownership enterprises' equity (Sun et al., 2005). Therefore, this study incorporates the efficiencies of state-owned and private capital into the model and analyses their roles further. Third, this study considers the role of government interventions. The government can use subsidies to influence the capacity decisions of enterprises, thereby impacting their capacity sharing behaviour and social welfare, which is under-examined in the existing literature (Chen, Xie, et al., 2020; Chen, Wang, & Liu, 2020). Through these three aspects of expansion, this study provides powerful theoretical support for enterprises' strategic decision-making and the formulation of government policies.

The remainder of this article is organised as follows: Section 2 summarises the literature regarding proportion of state-owned shares and capacity sharing. Section 3 introduces the research methodology and constructs a sequential game model that considers the proportion of state-owned shares and capacity sharing decisions. Section 4 obtains the equilibrium results under the three conditions and analyses the influence of the proportion of state-owned shares, capacity constraints, and capacity prices on the equilibrium results. Moreover, this section compares the equilibrium results in the three cases and examines the effects of the optimal state-owned shares and government subsidies. Finally, Section 5 concludes the study.

2. Literature review

This study focuses on two main issues: the proportion of state-owned shares and capacity sharing. There are different opinions in academia regarding the proportion of state-owned shares in enterprises. Some scholars believe that nationalisation is more beneficial; that is, they support increasing the proportion of state-owned shares in enterprises and exploring the mechanism of nationalisation. Li and Yu (2018) indicated that state-owned shares play an important role in reducing costs and controlling risk, which benefits enterprises' survival and development in a complex and volatile market environment. Liu, Wang, et al. (2021) argued that state-owned enterprises have more advantages in obtaining external financing, thereby protecting their investment opportunities from market fluctuations. Takeshi and Daisuke (2019) noted that nationalisation effectively improves social welfare and that increasing the proportion of state-owned shares benefits society. Therefore, they believe that a higher proportion of state-owned shares is beneficial from the perspective of corporate stability and social harmony. However, some scholars argue that reducing the proportion of state-owned shares is beneficial (Tao et al., 2021). Boubakri et al. (2017) explored the positive impact of privatisation on corporate efficiency and profitability. They believe the government must give up control and ownership for enterprises to achieve their goals. Cosset et al. (2020) indicated that state-owned ownership can lead to performance deterioration, and privatisation through the issuance of stocks can improve performance more than through the sale of assets. Fragoudaki and Giokas (2020) verified that privatisation could promote airport operational efficiency. Generally, they argue that privatisation can effectively alleviate the problems of information asymmetry and principal agents, improve the efficiency of enterprise operations, and optimise the governance structure. Other scholars argue that full nationalisation or privatisation cannot achieve the optimum (Matsumura, 1998; Zhang & Wang, 2022) and that mixed ownership is the optimal form of property rights. The proportion of state-owned shares is affected by factors such as enterprise conditions and the external market environment (Bel & Fageda, 2010; Chen, Zhang, et al., 2021; Cho et al., 2022; Pagliari & Graham, 2019). Xing and Tan (2021) claimed that environmental attitudes and tax rates affect the degree of privatisation of enterprises, thereby affecting social welfare, drawing on their research to deeply explore the impact of state-owned shares on social welfare. Liu, Matsumura, et al. (2021) showed that corporate interest rates affect the optimal degree of enterprise privatisation and that the minimum profit constraint is an important factor that needs to be considered when formulating privatisation policies. These studies provide insight for this study's analysis of the impact and optimal level of the proportion of state-owned shares, comprehensively considering these three issues: What is the role of state-owned shares? Is there an optimal proportion of state-owned shares? How does the government determine the optimal proportion? This study analysed the influence and optimal proportion of state-owned shares by incorporating state-owned shares into capacity sharing.

Relevant literature on capacity sharing is abundant. Capacity sharing has become an important means of strategic cooperation between enterprises (Fang & Wang, 2020; Sun et al., 2020; Xie & Han, 2020). They can share excess capacity and optimise capacity allocation by reaching a sharing agreement (Lai et al., 2019; Wei & Zhang, 2021; Zhao et al., 2020). In 2021, an outdoor product enterprise in Hangzhou faced a 60% surge in export orders for outdoor sports products from January to June. However, its production capacity could not be maintained.

Another hardware tool factory had redundant, idle factories that could meet the expanding production capacity needs of the outdoor product enterprise. After coordination, both parties reached a mutual agreement and decided to solve the joint problems of insufficient capacity and idle workshops simultaneously in the form of a shared workshop, leading to a win–win situation. The Jiande City government starts with the personality problems of enterprises and launches shared warehouses, employees, and other practices. Previous studies have investigated its effects, mechanisms, and strategy optimisation (Chen, Wei, et al., 2021; Qin, Liu, et al., 2020; Yu et al., 2015). Some scholars believe that capacity sharing is beneficial, whereas others have pointed out that the positive function of capacity sharing should be limited to certain conditions (Chen, Wang, et al., 2020; Qin, Wang, et al., 2020). For the influencing factors of capacity sharing, many scholars also have explored externalities, decision-making bodies, demand fluctuations, etc. Aloui and Jebsi (2016) study capacity sharing with shared externalities, arguing that capacity sharing is not only related to the participation of both parties but is critically affected by externalities. Benjaafar et al. (2019) analysed the impact of different decision-making entities on capacity sharing by comparing cases of maximising profit and welfare. They find that the equilibrium results of these two maximisation cases are different, but the difference is small. Liu, Hua et al. (2021) and Xiao et al. (2013) focused on the important impact of demand on capacity sharing and analyse the various effects of demand fluctuations. Roels and Tang (2017) examined two forms of strategic alliances – manufacturing capacity sharing and distribution capacity sharing – and specifically, explore the effects of timing. The literature on capacity sharing explores its form, conditions, and influence of capacity sharing. Based on these studies, this study explores the boundary conditions and influence of capacity sharing between enterprises in the presence of state-owned share ratios.

However, literature exploring the impact of the proportion of state-owned shares on capacity sharing is insufficient, which is the focus of this study. Therefore, the proposed models simultaneously include the proportion of state-owned shares and equity efficiency and focus on analysing their impacts on capacity sharing as a form of enterprise cooperation. In addition, the government's role is reflected in subsequent expansion. However, our models are still a simplification of reality under certain assumptions and, thus, remain different from reality. Therefore, it is necessary to conduct a more in-depth exploration of the model form and parameter meaning, as reflected in the conclusion.

3. Research methodology

We divide the two cases by Enterprise 1's capacity as sufficient or insufficient to answer the research questions. When Enterprise 1's capacity is insufficient, Enterprise 2 decides whether to share it. Second, based on the equilibrium results, we analyse the conditions for the two enterprises to reach capacity sharing and explore the impact of the capacity price. Third, we explore the optimal proportion of state-owned shares. Finally, we investigate government subsidies in different cases to highlight the government.

This study adopts a sequential game method to establish an oligopoly model that can provide a desirable tool for cooperation and competition between enterprises in different scenarios to achieve these objectives. An oligopoly market is a market structure between perfect competition and a perfect monopoly. This study employs a sequential game to explore the equilibrium outcomes of capacity sharing and competition between two competing enterprises. We constructed an oligopoly model of capacity sharing between two enterprises under Cournot competition.

This study constructs a mixed oligopoly model that considers the proportion of state-owned shares and capacity sharing, with the following assumptions:

Assumption 1. Suppose a Cournot competition model exists with two enterprises: a mixed-ownership enterprise (Enterprise 1) and a private enterprise (Enterprise 2). The production technologies of the two enterprises are the same, and the products are homogeneous. The demand function of enterprises is $P_i = a - q_i - q_j$ ($i, \ j = 1, \ 2$ and $\neq j$), where $a > 0, \ P_i$ is the price of the product, and q_i is the output of enterprise i, which is a formula that expresses the dependence between the demanded quantity of the commodity and the price (Chen, Wang, et al., 2021; Jain & Pal, 2012).

Assumption 2. Suppose Enterprise 1 is a mixed-ownership enterprise with both state-owned and non-state-owned shares, where a high value of β denotes a higher proportion of state-owned shares, $0 \leq \beta \leq 1$, and its marginal cost is $C_1 = \beta m + (1 - \beta)n$. Enterprise 2 is a private enterprise with a marginal cost of $C_2 = n$, the cost of state-owned capital is m, and n is the cost of private capital. Moreover, $m > n$, which means that the efficiency of private capital is higher than that of state-

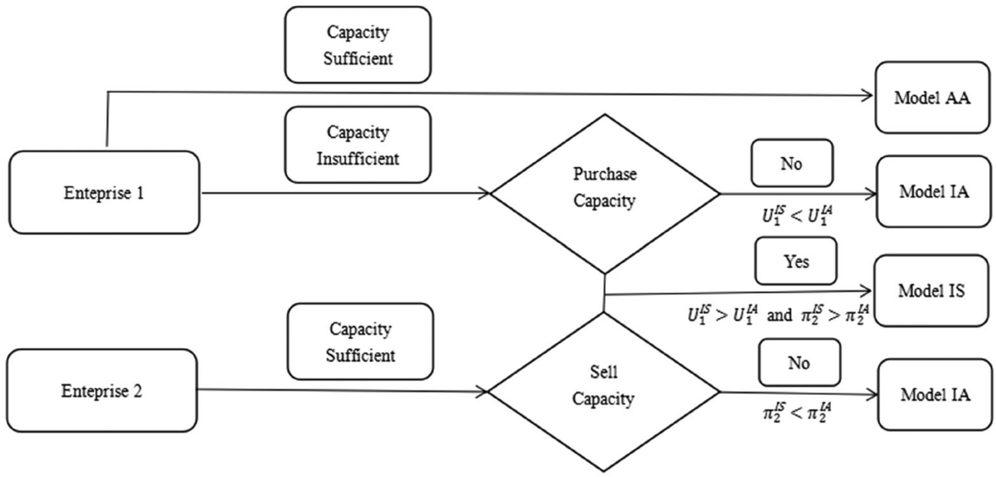

Figure 1. The competition model selection process.
Source: complied by authors.

owned capital; otherwise, mixed-ownership reform is meaningless. The larger m and $n$are, the lower the equity efficiency; therefore, the proportion of state-owned shares and equity efficiency are simultaneously included in the model, and the state-owned shares are analysed both quantitatively and qualitatively. In addition, to avoid overly complicated calculations, the upper limit of m is set as $a + 2n - 3m > 0$. The profit functions are $\pi_i = (P_i - C_i)q_i,\ i = 1,\ 2$. Social welfare is the sum of producer surplus and consumer surplus: $SW = \pi_1 + \pi_2 + CS$, where $CS = \frac{(q_1+q_2)^2}{2}$. Enterprise 1 pursues a mixed goal: it contains state-owned shares; thus, it not only cares about its profit but also considers social welfare. Thus, it maximises its utility, which is expressed in the form of $U_1 = (1-\beta)\pi_1 + \beta SW$, whereas Enterprise 2 pursues profit maximisation with a utility function of $U_2 = \pi_2$.

Assumption 3. The output of an enterprise depends not only on the goal of maximising utility but also on whether it has sufficient capacity. k_1 a constant, which means the upper capacity limit of Enterprise 1. If the capacity is sufficient, the output of Enterprise 1 can be produced according to the utility maximisation standard; otherwise, production can only occur under the capacity constraint, and utility-maximising output cannot be achieved. The superscripts AA, IA, and IS denote the equilibrium results in three cases: two enterprises have sufficient capacity, one enterprise has insufficient capacity, the other has overcapacity without capacity sharing, one has insufficient capacity, and the other has capacity sharing.

Because Enterprise 1 is a mixed-ownership enterprise and has the disadvantage of equity efficiency, it is assumed that Enterprise 1 alone would have insufficient capacity. Under the above assumptions, a two-stage sequential game was constructed. At the zero stage, enterprises judge their capacity status and choose a competition model. In the first stage, enterprises adopt capacity competition to maximise their utilities. In the second stage, enterprises decide their optimal output by maximising their utility. The enterprise selection and competition processes are shown in detail in Figure 1. Backward induction is used to derive equilibrium results.

4. Results and case study

Enterprises compete on their outputs. This study investigates these issues in a mixed oligopoly under Cournot competition. Specifically, the model is solved by backward induction, and the impacts of the parameters on the equilibrium results are analysed by seeking partial derivatives.

4.1. Model AA

First, suppose that the capacities of the two enterprises are sufficient and that the first-order condition $\frac{\partial U_i}{\partial q_i} = 0$ is satisfied based on the maximum utilities. Thus, we obtain the equilibrium outputs as follows:

$$q_1^{AA} = \frac{a-n+2(n-m)\beta}{3-2\beta} \tag{1}$$

$$q_2^{AA} = \frac{a-n-(a-m)\beta}{3-2\beta} \tag{2}$$

When $n < m < \frac{a+2n}{3}$, $q_1^{AA} > q_2^{AA}$. When the capacities of the two enterprises are sufficient, the output of the mixed-ownership enterprise is higher than that of the private enterprise.

Furthermore, the profit, consumer surplus, and social welfare are obtained according to the equilibrium outputs of the two enterprises.

Result 1. *The effects of β in Model AA:*
$\frac{\partial q_1^{AA}}{\partial \beta} > 0$, $\frac{\partial q_2^{AA}}{\partial \beta} < 0$, $\frac{\partial \pi_1^{AA}}{\partial \beta}$, if $0 \le \beta < \frac{1}{2}$ *and* $n < m \le m_1$, then $\frac{\partial \pi_1^{AA}}{\partial \beta} \ge 0$; *if* $0 \le \beta < \frac{1}{2}$ *and* $m_1 < m < \frac{a+2n}{3}$, *then* $\frac{\partial \pi_1^{AA}}{\partial \beta} < 0$; *if* $\frac{1}{2} \le \beta \le 1$, *then* $\frac{\partial \pi_1^{AA}}{\partial \beta} < 0$, where $m_1 = \frac{4\beta^2 n+(-2a-16n)\beta+a+11n}{4\beta^2-18\beta+12}$; $\frac{\partial \pi_2^{AA}}{\partial \beta} < 0$, $\frac{\partial CS^{AA}}{\partial \beta} > 0$, if $n < m \le m_2$, then $\frac{\partial SW^{AA}}{\partial \beta} \ge 0$; if $m_2 < m < \frac{a+2n}{3}$, then $\frac{\partial SW^{AA}}{\partial \beta} < 0$, where $m_2 = \frac{-\sqrt{\left(2\beta^2-5\beta+4\right)(-3+2\beta)^2(a-n)^2}+8\beta^3 n-36\beta^2 n+(-5a+38n)\beta+6a-6n}{8\beta^3-36\beta^2+33\beta}$.

Result 1 indicates that a higher proportion of state-owned shares (β) yields higher output and consumer surplus for Enterprise 1 but lower output and profit for Enterprise 2. Therefore, when the capacities of both enterprises are sufficient, if β increases, consumers benefit; however, private enterprises, as competitors, are harmful. When β and m are lower, Enterprise 1's profit increases with β. However, when the efficiency of state-owned capital is lower, Enterprise 1's profit decreases with β. When β is at a higher level, the higher β is, the lower Enterprise 1's profit is. Therefore, for mixed-ownership enterprises, only when β is low and the efficiency of state-owned capital is high does a continued increase in the proportion of state-owned shares help increase their profits; otherwise, if they blindly increase, profits decline. For society, a higher β value in mixed-ownership enterprises is not always better, which is also related to m. If $n < m \leq m_2$, it implies that the efficiency of state-owned capital is higher. As β increases, social welfare improves and vice versa. From a social welfare perspective, increasing the proportion of state-owned shares is a rational choice only when the efficiency of state-owned capital is high. Therefore, when determining β, enterprises with mixed ownership must consider two important interrelated factors: the current level of state-owned shares and the efficiency of state-owned capital. Governments should also formulate policies to guide the proportion of state-owned shares within an appropriate range.

4.2. Model IA

Suppose that Enterprise 1 has insufficient capacity, and its upper capacity limit is k_1. Enterprise 2 has both sufficient capacity and overcapacity. If there is no capacity sharing, the ceiling of Enterprise 1's capacity is k_1. To maximise utility, we derive the equilibrium outputs of both enterprises as follows:

$$q_1^{IA} = k_1 \tag{3}$$

$$q_2^{IA} = \frac{a-n-k_1}{2} \tag{4}$$

If $0 < k_1 \leq \frac{a-n}{3}$, then $q_1^{IA} \leq q_2^{IA}$; if $\frac{a-n}{3} < k_1 < \frac{a-n+2(n-m)\beta}{3-2\beta}$, then $q_1^{IA} > q_2^{IA}$. In other words, when there is insufficient capacity without capacity sharing, the output of the mixed-ownership enterprise is lower than that of the private enterprise only when the capacity constraints are severe.

Analysing the impact of k_1 and β on output, profit, consumer surplus, and social welfare, we obtain Results 2-1 and 2-2.

Result 2-1. *The effects of k_1 in Model LA:*
$\frac{\partial q_1^{IA}}{\partial k_1} > 0$, $\frac{\partial q_2^{IA}}{\partial k_1} < 0$, if $0 \leq \beta \leq \frac{1}{2}$, then $\frac{\partial \pi_1^{IA}}{\partial k_1} > 0$; if $\frac{1}{2} < \beta \leq 1$ *and* $0 < k_1 \leq \frac{a-n-2(m-n)\beta}{3}$, then $\frac{\partial \pi_1^{IA}}{\partial k_1} \geq 0$; if $\frac{1}{2} < \beta \leq 1$ *and* $\frac{a-n-2(m-n)\beta}{3} < k_1 \leq \frac{a-n+2(n-m)\beta}{3-2\beta}$, then $\frac{\partial \pi_1^{IA}}{\partial k_1} < 0$; $\frac{\partial \pi_2^{IA}}{\partial k_1} < 0$, $\frac{\partial CS^{IA}}{\partial k_1} > 0$ *if* $0 \leq \beta \leq \frac{a+5m-6n-\sqrt{a^2-6am+4an+25m^2-44mn+20n^2}}{8(m-n)}$, then $\frac{\partial SW^{IA}}{\partial k_1} > 0$; $\frac{a+5m-6n-\sqrt{a^2-6am+4an+25m^2-44mn+20n^2}}{8(m-n)} < \beta \leq 1$ *and* $0 < k_1 \leq a - n - 4(m-n)\beta$, then $\frac{\partial SW^{IA}}{\partial k_1} \geq 0$, if $\frac{a+5m-6n-\sqrt{a^2-6am+4an+25m^2-44mn+20n^2}}{8(m-n)} < \beta \leq 1$ *and* $a - n - 4(m-n)\beta < k_1 \leq \frac{a-n+2(n-m)\beta}{3-2\beta}$, then $\frac{\partial SW^{IA}}{\partial k_1} < 0$.

Result 2-2. *The effects of β in Model LA:*

$$\frac{\partial q_1^{IA}}{\partial \beta} = \frac{\partial q_2^{IA}}{\partial \beta} = \frac{\partial \pi_2^{IA}}{\partial \beta} = \frac{\partial CS^{IA}}{\partial \beta} = 0, \quad \frac{\partial \pi_1^{IA}}{\partial \beta} < 0, \quad \frac{\partial SW^{IA}}{\partial \beta} < 0.$$

When Enterprise 1 has insufficient capacity and Enterprise 2 does not share capacity, Enterprise 1's output and consumer surplus are positively correlated with k_1, whereas Enterprise 2's output and profit are negatively correlated with k_1, implying that the more severe the capacity constraints Enterprise 1 faces, the more advantageous it is for its competitors but disadvantageous for consumers. The relationship between the profit and capacity of Enterprise 1 is affected by β. If β is low, Enterprise 1's profit is positively correlated with k_1 and vice versa. Therefore, when β is lower, Enterprise 1 has an incentive to increase its capacity; however, if β exceeds a certain level, the enterprise will consider whether to alleviate capacity constraints by considering the current capacity level. The relationship between social welfare and k_1 is consistent with that between Enterprise 1's profit and k_1, with the exception that the critical value is different. Therefore, when Enterprise 1 has a lower β or faces more severe capacity constraints, raising the upper capacity limit benefits social welfare. Otherwise, social welfare may reduce because of overcapacity. With capacity constraints, enterprises and the government should consider the issue of capacity from the perspective of enterprises' equity structure and market competition.

Without capacity sharing, the outputs of both enterprises, Enterprise 2's profit, and the consumer surplus are unrelated to the proportion of state-owned shares, indicating that the impact of capacity constraints is dominant. Enterprise 1's profit and social welfare are negatively related to β. Therefore, when facing capacity constraints without capacity sharing, appropriately reducing the proportion of state-owned shares helps to increase profits and social welfare.

4.3. Model IS

If capacity sharing is achieved, suppose Enterprise 2 has sufficient capacity to meet the needs of Enterprise 1, and Enterprise 2 is willing to share that capacity but charges a certain fee for each unit of shared capacity. At this time, Enterprise 1 is not concerned about insufficient capacity but needs to consider the issue of cost payments. The profit functions of the two enterprises are as follows:

$$\pi_1 = (a - c_1 - q_1 - q_2)q_1 - (q_1 - k_1)b \tag{5}$$

$$\pi_2 = (a - c_2 - q_2 - q_1)q_2 + (q_1 - k_1)b \tag{6}$$

Solving the equilibrium outputs by maximising the utilities of the enterprise is as follows:

$$q_1^{IS} = \frac{2\beta b - 2\beta m + 2\beta n + a - 2b - n}{3 - 2\beta} \tag{7}$$

$$q_2^{IS} = \frac{(a + b - m)\beta - a - b + n}{-3 + 2\beta} \tag{8}$$

To ensure $q_1^{IS} > 0$ and $q_2^{IS} > 0$, we can obtain $0 < b < \frac{-2\beta m + 2\beta n + a - n}{2(1-\beta)}$.

If $0 < b \le \frac{\beta(a-3m+2n)}{3(1-\beta)}$, then $q_1^{IS} \ge q_2^{IS}$; if $\frac{\beta(a-3m+2n)}{3(1-\beta)} < b < \frac{-2\beta m + 2\beta n + a - n}{2(1-\beta)}$, then $q_1^{IS} < q_2^{IS}$.

When the capacity price is low, the output of mixed-ownership enterprises remains higher than that of private enterprises.

If capacity sharing is to be realised, it is necessary to satisfy Enterprise 1's incentive to purchase Enterprise 2's capacity ($U_1^{IS} > U_1^{IA}$), and Enterprise 2 is willing to sell its capacity ($\pi_2^{IS} > \pi_2^{IA}$). The reasonable price ranges to realise capacity sharing is as follows: if $0 < \beta < \frac{2k_1}{a+k_1-n}$, then $b_2 < b < b_4$; if $\frac{2k_1}{a+k_1-n} \le \beta \le \frac{2k_1}{a+k_1-2m+n}$, then $b_1 < b < b_4$; that is, $0 < \beta \le \frac{2k_1}{a+k_1-2m+n}$ and $max\{b_1, b_2\} < b < b_4$, *where* $b_1 = \frac{2(k_1-m+n)\beta+a-3k_1-n}{2(1-\beta)}$, $b_2 = \frac{2(2a+5m-7n-3k_1)\beta^2-(11a+16m-27n-17k_1)\beta+4(2a-2n-3k_1)}{2(5\beta^2-13\beta+8)}$, *and* $b_4 = \frac{2(2a-m-n-k_1)\beta-5a+5n+3k_1}{2(3\beta-5)}$. Thus, the two enterprises implement capacity-sharing. Chen, Wang, and Chu (2020) also believe that capacity sharing can be achieved only when both companies are profitable, and the fees for capacity sharing should not be too high or too low. However, the scope and impact of the proportion of state-owned shares are not considered.

Therefore, when the proportion of state-owned shares is different, the range of capacity prices under which capacity sharing can be realised also changes. Under model IS, the effects of β and b are obtained as follows:

Result 3-1. *The effects of β in model IS:*
$\frac{\partial q_1^{IS}}{\partial \beta} > 0$, $\frac{\partial q_2^{IS}}{\partial \beta} > 0$, $\frac{\partial \pi_1^{IS}}{\partial \beta} < 0$, if $0 \le \beta \le \frac{2k_1}{a+k_1-2m+n}$ and $max\{b_1, b_2\} < b \le \frac{a-n-(a-m)\beta}{2-\beta}$, $\frac{\partial \pi_2^{IS}}{\partial \beta} < 0$; if $0 \le \beta \le \frac{2k_1}{a+k_1-2m+n}$ and $\frac{a-n-(a-m)\beta}{2-\beta} < b < b_4$, $\frac{\partial \pi_2^{IS}}{\partial \beta} > 0$; $\frac{\partial CS^{IS}}{\partial \beta} > 0$, $\frac{\partial SW^{IS}}{\partial \beta} > 0$.

Result 3-2. *The effects of b in model IS:*
$\frac{\partial q_1^{IS}}{\partial b} < 0$, $\frac{\partial q_2^{IS}}{\partial b} > 0$, $\frac{\partial \pi_1^{IS}}{\partial b} < 0$, if $0 \le \beta \le \frac{2k_1}{a+k_1-2m+n}$ and $max\{b_1, b_2\} < b \le \frac{2(a-2k_1+m-2n)\beta^2-2(3a-6k_1+2m-5n)\beta+5a-5n-9k_1}{2(3\beta^2-8\beta+5)}$, $\frac{\partial \pi_2^{IS}}{\partial b} > 0$; if $0 \le \beta \le \frac{2k_1}{a+k_1-2m+n}$ and $\frac{2(a-2k_1+m-2n)\beta^2-2(3a-6k_1+2m-5n)\beta+5a-5n-9k_1}{2(3\beta^2-8\beta+5)} < b < b_4$, $\frac{\partial \pi_2^{IS}}{\partial b} < 0$, $\frac{\partial CS^{IS}}{\partial b} < 0$, $\frac{\partial SW^{IS}}{\partial b} < 0$.

Result 3-1 reveals that as β decreases, Enterprise 1's output declines, whereas Enterprise 1's profit, Enterprise 2's output, consumer surplus, and welfare surplus increase. This implies that after capacity sharing, Enterprise 1 is motivated to decrease β. At this time, although Enterprise 1's output is reduced, its profit increases because of capacity-sharing. When the capacity price is lower, Enterprise 2's profit increases in b. Therefore, within a specific range of β, only when b is low, Enterprise 2 is willing to support Enterprise 1 to reduce β, thereby increasing its profits. Thus, on the premise that capacity sharing can be achieved if the capacity price is low, reducing β in a mixed-ownership enterprise is an optimal decision for all stakeholders.

Result 3-2 implies that capacity price also affects equilibrium results. Enterprise 1's output and profit, consumer surplus, and social welfare are all negatively correlated with b, Enterprise 2's output is positively correlated with b, and Enterprise 2's profit is first positive and then negatively related to b. This shows that increasing the capacity price reduces capacity purchasers' profit, consumer surplus, and social welfare and has a limited effect on the profit improvement of capacity providers. Guo and Wu (2018) also found that when enterprises' capacity is asymmetric, capacity sharing may intensify competition and hurt profitability. Therefore, the formulation and

Table 1. Comparison of Model IA and Model AA.

Comparison	Results
$q_1^{IA} - q_1^{AA}$	$\frac{(-2m+2n+2k_1)\beta+a-n-3k_1}{-3+2\beta} < 0$
$q_2^{IA} - q_2^{AA}$	$\frac{(2m-2n-2k_1)\beta-a+n+3k_1}{-6+4\beta} > 0$
$\pi_1^{IA} - \pi_1^{AA}$	$\frac{((-2m+2n+2k_1)\beta+a-n-3k_1)\left((-2m+2n)\beta^2+(a+2m-3n-k_1)\beta-a+n+\frac{3}{2}k_1\right)}{(-3+2\beta)^2} < 0$
$\pi_2^{IA} - \pi_2^{AA}$	$-\frac{((-2m+2n+2k_1)\beta+a-n-3k_1)\left(\left(a-\frac{1}{2}m-\frac{1}{2}n-\frac{1}{2}k_1\right)\beta-\frac{5}{4}a+\frac{5}{4}n+\frac{3}{4}k_1\right)}{(-3+2\beta)^2} > 0$
$CS^{IA} - CS^{AA}$	$\frac{((-2m+2n+2k_1)\beta+a-n-3k_1)\left((2a+m-3n+k_1)\beta-\frac{7}{2}a+\frac{7}{2}n-\frac{3}{2}k_1\right)}{4(-3+2\beta)^2} < 0$
$SW^{IA} - SW^{AA}$	$\frac{((-2m+2n+2k_1)\beta+a-n-3k_1)\left(8(n-m)\beta^2+(2a+11m-13n-k_1)\beta-\frac{5}{2}a+\frac{5}{2}n+\frac{3}{2}k_1\right)}{4(-3+2\beta)^2} < 0$

Source: The authors.

Table 2. Comparison of Model IS and Model IA.

Comparison	Results
$q_1^{IS} - q_1^{IA}$	$\frac{(-2b+2m-2n-2k_1)\beta-a+2b+n+3k_1}{-3+2\beta} < 0$
$q_2^{IS} - q_2^{IA}$	$\frac{(2b-2m+2n+2k_1)\beta+a-2b-n-3k_1}{-6+4\beta} > 0$
$\pi_1^{IS} - \pi_1^{IA}$	$\frac{\left((-2m+2n)\beta^2+(a-b+2m-3n-k_1)\beta-a+2b+n+\frac{3}{2}k_1\right)\left(\begin{array}{c}(2b-2m+2n+2k_1)\beta+\\ a-2b-n-3k_1\end{array}\right)}{-(-3+2\beta)^2} > 0$
$\pi_2^{IS} - \pi_2^{IA}$	$\frac{((2b-2m+2n+2k_1)\beta+a-2b-n-3k_1)\left(\left(a-\frac{3}{2}b-\frac{1}{2}m-\frac{1}{2}n-\frac{1}{2}k_1\right)\beta-\frac{5}{4}a+\frac{5}{2}b+\frac{5}{4}n+\frac{3}{4}k_1\right)}{(-3+2\beta)^2} > 0$
$CS^{IS} - CS^{IA}$	$\frac{\left((2a-b+m-3n+k_1)\beta-\frac{7}{2}a+b+\frac{7}{2}n-\frac{3}{2}k_1\right)((2b-2m+2n+2k_1)\beta+a-2b-n-3k_1)}{-4(-3+2\beta)^2} > 0$
$SW^{IS} - SW^{IA}$	$\left[8(n-m)\beta^2+(2a+b+11m-13n-k_1)\beta-\frac{5}{2}a-b+\frac{5}{2}n+\frac{3}{2}k_1\right]\left[\frac{(2b-2m+2n+2k_1)\beta+a-2b-n-3k_1]}{-4(-3+2\beta)^2>0}\right.$

Source: The authors.

Table 3. Comparison of Model IS and Model AA.

Comparison	Results
$q_1^{IS} - q_1^{AA}$	$\frac{2b(1-\beta)}{-3+2\beta} < 0$
$q_2^{IS} - q_2^{AA}$	$\frac{b(\beta-1)}{-3+2\beta} > 0$
$\pi_1^{IS} - \pi_1^{AA}$	$\frac{2\left(\begin{array}{c}(-2m+2n)\beta^3+(a-b+5m-6n-2k_1)\beta^2+\\ \left(-\frac{5}{2}a+3b-4m+\frac{13}{2}n+6k_1\right)\beta+2a-2b-2n-\frac{9}{2}k_1\end{array}\right)b}{-(-3+2\beta)^2} < 0$
$\pi_2^{IS} - \pi_2^{AA}$	$\frac{2\left((a-1.5b+m-2n-2k_1)\beta^2+(-3a+4b-2m+5n+6k_1)\beta+\frac{5}{2}a-\frac{5}{2}b-\frac{5}{2}n-\frac{9}{2}k_1\right)b}{(-3+2\beta)^2} > 0$
$CS^{IS} - CS^{AA}$	$\frac{(1-\beta)b\left((-4m+4n)\beta^2+\left(a+\frac{1}{2}b+5m-6n\right)\beta-a-\frac{1}{2}b+n\right)}{(-3+2\beta)^2} < 0$
$SW^{IS} - SW^{AA}$	$\frac{(1-\beta)b\left((-4m+4n)\beta^2+\left(a+\frac{1}{2}b+5m-6n\right)\beta-a-\frac{1}{2}b+n\right)}{(-3+2\beta)^2} < 0$

Source: The authors.

adjustment of capacity prices must be considered carefully to avoid adverse effects (Tables 1–3).

The parameter range is limited to the following: $n < m < \frac{a+2n}{3}$, $0 < k_1 < \frac{a-n+2(n-m)\beta}{3-2\beta}$, $0 \le \beta \le \frac{2k_1}{a+k_1-2m+n}$, and $max\{b_1, b_2\} < b < b_4$.

Result 4-1. *As shown in Table 1, comparing the equilibrium results of Model IA and Model AA, the following results can be obtained:*

$$q_1^{IA} < q_1^{AA},\ q_2^{IA} > q_2^{AA},\ \pi_1^{IA} < \pi_1^{AA}, \pi_2^{IA} > \pi_2^{AA}, CS^{IA} < CS^{AA}, \text{ and } SW^{IA} < SW^{AA}.$$

Result 4-2. *As shown in Table 2, comparing the equilibrium results of model IS and Model IA, the following results can be obtained:*
$q_1^{IS} < q_1^{IA}$, $q_2^{IS} > q_2^{IA}$, $\pi_1^{IS} > \pi_1^{IA}$, $\pi_2^{IS} > \pi_2^{IA}$, $CS^{IS} < CS^{IA}$, and $SW^{IS} < SW^{IA}$.

Result 4-3. *As shown in Table 3, comparing the equilibrium results of model IS and Model AA, the following results can be obtained:*
$q_1^{IS} < q_1^{AA}$, $q_2^{IS} > q_2^{AA}$, $\pi_1^{IS} < \pi_1^{AA}$, $\pi_2^{IS} > \pi_2^{AA}$, $CS^{IS} < CS^{AA}$, and $SW^{IS} < SW^{AA}$.

Result 4-4. *Comparing the equilibrium results of Model AA, Model IA, and Model IS, the following results can be obtained:*
$q_1^{AA} > q_1^{IA} > q_1^{IS}$, $q_2^{IS} > q_2^{IA} > q_2^{AA}$, $\pi_1^{AA} > \pi_1^{IS} > \pi_1^{IA}$, $\pi_2^{IS} > \pi_2^{IA} > \pi_2^{AA}$, $CS^{AA} > CS^{IA} > CS^{IS}$, and $SW^{AA} > SW^{IA} > SW^{IS}$.

Compared with Model AA, Enterprise 1's output and profit, as well as consumer surplus and social welfare, are lower in Model IA. However, the output and profit of Enterprise 2 increased. These results imply that Enterprise 1's profits, consumers, and society are harmed when there is insufficient capacity. As a competitor, Enterprise 2 benefits from its capacity constraints. Therefore, it is necessary to alleviate the capacity constraints from the perspective of Enterprise 1, consumers, and society.

Compared to Model IA, Enterprise 1's output, consumer surplus, and social welfare are reduced in model IS. Meanwhile, Enterprise 2's output and profits increased for both enterprises. Qin, Wang, et al. (2020) find that profit increases in enterprises with capacity constraints if capacity sharing is present. Therefore, capacity sharing enables the effective allocation of resources and increases enterprise profitability. Taking Shenyang Machine Tool Factory as an example, it has launched an 'intelligent machine tool'; other enterprises can use it by paying service fees and purchasing the processing capacity of the machine tool. The Shenyang Machine Tool Factory can increase its income by renting and selling it on behalf of others. However, because the proportion of state-owned shares and capacity prices is limited to certain ranges under capacity sharing, consumers and society do not benefit. Chen, Shi, et al. (2022) suggest that capacity sharing may not improve social welfare. This indicates that when a mixed-ownership enterprise faces capacity constraints, it is the consensus of the enterprise to share capacity; however, consumers and the government do not support this activity from their perspective.

Compared to Model AA, Enterprise 1's output and profit, as well as consumer surplus and social welfare, are reduced in model IS. Enterprise 2's output and profit increase. This implies that capacity sharing only benefits capacity providers but does not contribute to capacity demanders, consumers, or society compared to when capacity is sufficient, which supports an effective governance overcapacity. Consistent with the comparison results between model IS and Model IA, this further illustrates that government intervention is required to ensure that capacity sharing benefits stakeholders and that the pure market competition mechanism is ineffective.

Enterprise 1's output, consumer surplus, and social welfare are highest when both enterprises have sufficient capacity and lowest when capacity sharing is achieved. Enterprise 1's profit is highest when both enterprises have sufficient capacity, followed by capacity sharing, and lowest when there is insufficient capacity; one enterprise has overcapacity without capacity sharing. The output and profit of Enterprise 2 are highest when capacity is shared, and an enterprise with overcapacity but not sharing takes an intermediate value, while it is lowest when both enterprises have sufficient capacity. In particular, the capacity choices of different entities vary. For Enterprise 1, profit is highest when the capacity is sufficient. When capacity is insufficient, selecting capacity sharing increases profits. For Enterprise 2, capacity sharing is the most beneficial to the increase in output and profit. Alibaba Cloud and Foxconn jointly created the 'Tao Fu Come True' project to provide entrepreneurs with full-chain services, such as intellectual property, industrial design, and manufacturing. Enterprises can share not only the computing resources of Alibaba Cloud but also the manufacturing capabilities of Foxconn, which effectively solves the problems of lack of technology and talent in the development of enterprises; in terms of consumer surplus and social welfare, capacity sharing does not improve. Therefore, consumers and the government may not support capacity sharing, posing new challenges to its realisation.

4.4. Expansion

In addition to the above analysis, state-owned shares and government subsidies play an important role in capacity sharing, requiring in-depth analysis.

4.4.1. Optimal proportion of state-owned shares

In the modern market economy, state-owned enterprises and private enterprises coexist, and state-owned equity affects the goals of enterprises, which inevitably affects the realisation and effect of capacity sharing. For example, the China National Building Materials Group, a state-owned enterprise, promotes the transformation of its enterprises that face serious overcapacity into enterprises with industrial chain manufacturing service functions. Thus, its performance was significantly improved. It also turns competitors into partners through market synergy and promotes the construction of regional marketing platforms, suggesting that state-owned shares play an important role in capacity sharing, which requires in-depth analysis. Therefore, the game was expanded into three stages. In the first stage, the government determines the optimal proportion of state-owned shares. In the second stage, enterprises determine whether to implement capacity-sharing. Finally, enterprises decide their optimal outputs by maximising their utility. The latter two stages are investigated, and the first stage is explored.

Result 5. *In Model AA, if* $n < m \leq m_2$, *then* $\frac{\partial SW^{AA}}{\partial \beta} \geq 0$; *if* $m_2 < m < \frac{a+2n}{3}$, *then* $\frac{\partial SW^{AA}}{\partial \beta} < 0$. *Thus, there is* $\beta = f(a, m)$ *satisfies* $\frac{\partial SW^{AA}}{\partial \beta} = 0$; *in model IA,* $\frac{\partial SW^{IA}}{\partial \beta} < 0$,. *To maximise social welfare, the government support privatisation; in model IS,* $\frac{\partial SW^{IS}}{\partial \beta} > 0$, $\beta^* = \frac{2k_1}{a+k_1-2m+n}$.

Result 5 shows the optimal proportion of state-owned shares for the three cases. When the capacities of both enterprises are sufficient, the government can choose a proportion between 0 and 1 to maximise social welfare. Once capacity constraints exist, full privatisation is the best choice for the government. The government determines the highest proportion under the premise of ensuring capacity-sharing. Therefore, when capacity differs, the government must adjust its policies accordingly. Privatisation and mixed ownership can both be optimal choices under certain conditions. Li et al. (2019) note that a set of capacity-efficiency frontiers exists beyond which the public–private duopoly performs better than non-privatisation. It can be seen that the proportion of state-owned shares is related to capacity, and privatisation may be a better choice in certain cases.

4.4.2. Government subsidies

In reality, many governments attach great importance to the development of the digital economy and provide substantial subsidies to the digital economy, which provides good conditions for capacity sharing. Considering China as an example, a single project can reach up to one million yuan from the perspective of subsidy standards. As for subsidy amount, subsidies in core areas of the digital economy such as 'platform economy, satellite applications, artificial intelligence, Internet of Things, 5th Generation Mobile Communication Technology (5G)' have reached 100 million yuan. Therefore, government subsidies have significantly promoted the digital economy's development, especially in realising capacity sharing. Considering the case in which the government provides subsidies, we ensure that social welfare can increase when enterprises 1 and 2 are willing to share capacity, namely $SW^{IS} > SW^{IA}$.

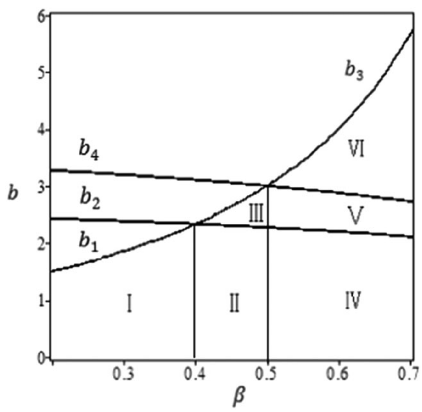

Figure 2. [1] The feasible range of $SW^{IS} > SW^{IA}$.
Source: complied by authors.

Table 4. The areas of $SW^{IS} > SW^{IA}$

Ranges	Areas
$0 < \beta \leq \frac{2k_1}{a+k_1-n}$	$U_1^{IS} > U_1^{IA}$ and $\pi_2^{IS} < \pi_2^{IA}$ (area I)
$\frac{2k_1}{a+k_1-n} < \beta < \frac{2k_1}{a+k_1-2m+n}$	if $0 < b < b_2$, then $U_1^{IS} > U_1^{IA}$ and $\pi_2^{IS} < \pi_2^{IA}$ (area II)
	if $b_2 < b < b_1$, then $U_1^{IS} < U_1^{IA}$ and $\pi_2^{IS} < \pi_2^{IA}$ (area III)
$\frac{2k_1}{a+k_1-2m+n} < \beta < 1$	if $0 < b < b_2$, then $U_1^{IS} > U_1^{IA}$ and $\pi_2^{IS} < \pi_2^{IA}$ (area IV)
	if $b_2 < b < b_4$, then $U_1^{IS} < U_1^{IA}$ and $\pi_2^{IS} < \pi_2^{IA}$ (area V)
	if $b_4 < b < b_3$, then $U_1^{IS} < U_1^{IA}$ and $\pi_2^{IS} > \pi_2^{IA}$ (area VI)

Source: The authors.

As shown in Figure 2 and Table 4, when the capacity price is low, capacity sharing benefits Enterprises 1. At this time, the utility of Enterprise 1 with capacity sharing is higher than the utility of non-capacity sharing. For Enterprise 2, only when b and β are high, the profit from capacity sharing is higher than that without it, and it should be willing to take the initiative to share capacity. Therefore, the government must fully consider the impact of these two factors and formulate a more targeted subsidy policy, leading to Corollary 2.

Suppose s_1, s_2, and s_3 are as follows:

$$s_1 = U_1^{IA} - U_1^{IS} = \frac{\begin{array}{c}[2(2a-5b+5m-7n-3k_1)\beta^2-(11a-26b+16m-27n-17k_1)\beta+ \\ 4(2a-4b-2n-3k_1)][2(k_1+n-m+b)\beta+a-2b-n-3k_1]\end{array}}{-8(2\beta-3)^2} \tag{9}$$

$$\begin{aligned} s_2 &= \pi_2^{\mathrm{IA}} - \pi_2^{\mathrm{IS}} \\ &= \frac{[2(2a-3b-m-n-k_1)\beta-(5a-5b-5n-3k_1)][2(k_1+n-m+b)\beta+a-2b-n-3k_1]}{-8(2\beta-3)^2} \end{aligned} \tag{10}$$

$$s_3 = SW^{IS} - SW^{IA} = \frac{\begin{array}{c}[8(n-m)\beta^2+2(2a+b+11m-13n-k_1)\beta-(5a+2b-5n \\ -3k_1)][2(k_1+n-m+b)\beta+a-2b-n-3k_1]\end{array}}{8(2\beta-3)^2} \tag{11}$$

The feasible range of subsidies is $\frac{2k_1}{a+k_1-2m+n} < \beta < 1$ and $max\{b_5, b_6\} < b < min\{b_7, b_1\}$, where $b_5 = \frac{16(m-n)\beta^2+2(2a-k_1-13m+11n)\beta-5a+3k_1+5n}{2(7\beta-11)}$, $b_6 = \frac{2(2a+13m-15n-3k_1)\beta^2-(7a+42m-49n-15k_1)\beta+3(a-n-3k_1)}{2\left(5\beta^2-6\beta-3\right)}$, $b_7 = \frac{2(2a+13m-15n-3k_1)\beta^2-(15a+38m-53n-19k_1)\beta+13a-13n-15k_1}{2\left(5\beta^2-12\beta+7\right)}$. To simplify, suppose that $A = \{-48(a-3m+2n){k_1}^3+[105m^2-6(38-3n)m+24a^2+180an-99n^2]\ {k_1 2}+ \left[\begin{array}{c}1728m^3-8(177a+471n)m^2+8(21a^2+312an+315n^2)m- \\ 3a^3-159a^2n-1089n^2a-477n^3\end{array}\right]k_1 \quad -48(m-n)^2 \left[256m^2-16(3a+254n)m+a^2+46an+209n^2\right]\}^{\frac{1}{2}}$; $C = \left\{\begin{array}{c}30(m-n)A-64{k_1}^3+16(3a-252m+24n){k_1}^2+ \\ [-12a^2+12(33m-31n)a-2502m^2+4608mn-2118n^2]k_1 \\ +[a^2-2(24m-23n)a+216m^2-384mn+169n^2](a-24m+23n)\end{array}\right\}^{\frac{1}{3}}$; $D = 16{k_1}^2-8(a-9m+8n)k_1+a^2-2(24m-23n)a+336m^2-624mn+289n^2$, the areas of subsidies are shown in Table 5.

Table 5. The areas of subsidies.

Areas	Subsidies
If $\frac{2k_1}{a+k_1-2m+n} < \beta < \frac{2k_1}{a+k_1-n}$ and $b_5 < b < b_1$, $\frac{2k_1}{a+k_1-n} < \beta < \frac{2k_1}{a+k_1-2m+n}$ and $b_5 < b < b_2$ as well as $\frac{2k_1}{a+k_1-2m+n} < \beta < \frac{2(a-4k_1+36m-37na-4k_1+36m-37n)C-C^2-D}{60(m-n)C} + \left\{\frac{3}{4}\left(\frac{D}{30(m-n)C} - \frac{C}{30(m-n)}\right)\right\}^{\frac{1}{2}}$ and $b_5 < b < b_2$ (area VII)	Only subsidise Enterprise 2, and the range of subsidies is $s_2 < s < s_3$
If $\frac{2k_1}{a+k_1-n} < \beta < \frac{2k_1}{a+k_1-2m+n}$ and $b_6 < b < b_1$, $\frac{2k_1}{a+k_1-2m+n} < \beta < \frac{2(a-4k_1+36m-37na-4k_1+36m-37n)C-C^2-D}{60(m-n)C} + \left\{\frac{3}{4}\left(\frac{D}{30(m-n)C} - \frac{C}{30(m-n)}\right)\right\}^{\frac{1}{2}}$ and $b_6 < b < b_4$, *as well as* $\frac{2(a-4k_1+36m-37na-4k_1+36m-37n)C-C^2-D}{60(m-n)C} + \left\{\frac{3}{4}\left(\frac{D}{30(m-n)C} - \frac{C}{30(m-n)}\right)\right\}^{\frac{1}{2}} < \beta < 1$ and $b_6 < b < b_4$ (area VII)	Subsidise Enterprise 1 and Enterprise 2, and the range of subsidies is $s_1 + s_2 < s < s_3$
If $\frac{2k_1}{a+k_1-2m+n} < \beta < \frac{2k_1}{a+k_1+4m-5n}$ and $b_4 < b < b_1$ as well as $\frac{2k_1}{a+k_1+4m-5n} < \beta < 1$ and $b_7 < b < b_1$ (area VIII)	Only subsidise Enterprise 1, and the range of subsidies is $s_1 < s < s_3$

Source: The authors.

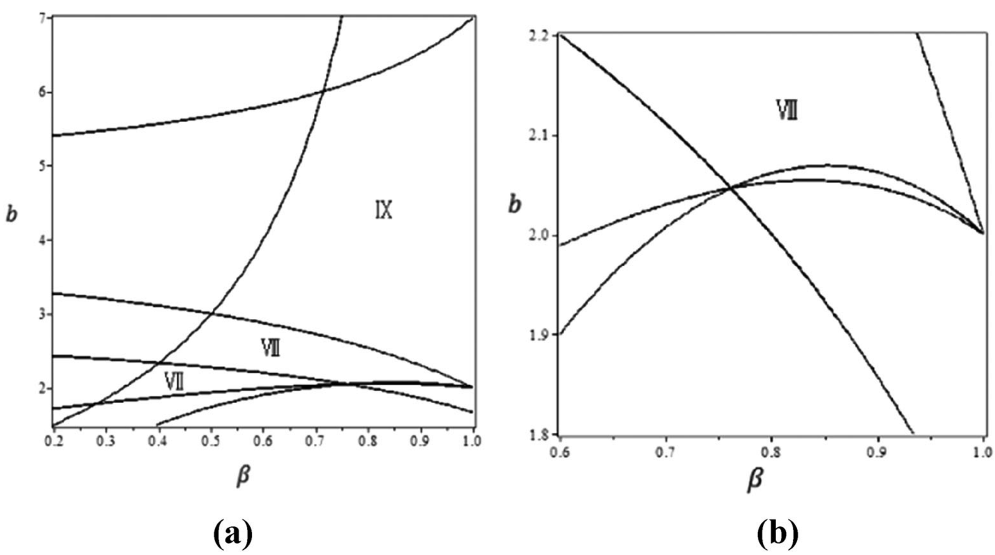

Figure 3. The feasible range of subsidies.
Source: complied by authors.

Figure 3 and Table 5 imply that when the proportion of state-owned shares and capacity prices are within a specific range, the government can promote capacity sharing through subsidies. The subsidy targets vary because of the different scopes of these two factors, the results are shown in Table 5. When β and b are both low, the government should subsidise Enterprise 2. When β and b are high, the government should subsidise Enterprise 1 to promote capacity sharing more effectively when the capacity price is relatively moderate. The government needs to increase subsidies to subsidise both enterprises. Therefore, the government intervenes in enterprises' capacity decision-making behaviour through subsidies, simultaneously promoting capacity sharing and increasing social welfare simultaneously.

5. Conclusions

This study analyses the equilibrium results in three scenarios, revealing the multiple effects of the state-owned share proportion (β) and capacity sharing and draws the following conclusions.

First, the proportion of state-owned shares has complex effects on market participants, which are related to the efficiency of state-owned capital. In Model IA, β has no impact on the outputs of both enterprises, Enterprise 2's profit or consumer surplus. In Model AA, the impact of β on Enterprise 1's profit and social welfare is affected by state-owned capital efficiency. When β is low and the efficiency of state-owned capital is low, or β is already high, Enterprise 1 has an incentive to reduce β. However, the government has an incentive to reduce β when state-owned capital efficiency is lower.

Second, capacity constraints and capacity prices affect the equilibrium results. In Model IA, if β exceeds a certain level, the capacity constraint level is negatively correlated with social welfare. Therefore, the decision on whether the capacity constraints should be alleviated and to what extent should be made in conjunction with the state-owned share decisions of mixed-ownership enterprises. In the case of capacity sharing, an optimal capacity price exists for enterprise 2. A blindly increasing price increases output but causes a decline in profit. However, owing to the existence of capacity prices, capacity demanders, consumers, and society do not benefit. Thus, promoting the development of the digital economy to reduce transaction fees and production costs may be a good choice.

Third, capacity sharing can effectively allocate resources to improve enterprises' profits; however, the capacity decisions made by different stakeholders vary, and such conflicts require policies for alleviation. When the b is low, Enterprise 1 is willing to purchase capacity, whereas Enterprise 2 is unwilling to share. When b and β are both high, Enterprise 2 is willing to share capacity, whereas Enterprise 1 is unwilling to buy. Hence, capacity sharing cannot be realised, social welfare is reduced, and enterprises in transportation, energy, manufacturing, and other industries should fully consider the effects of their capacity sharing activities.

Fourth, the optimal proportion of state-owned shares in the three cases differs, and privatisation and mixed ownership may be the optimal choices. Therefore, for enterprises and the government, the efficiency of state-owned capital must be considered when implementing mixed-ownership reforms, particularly in determining the proportion of state-owned shares.

Fifth, government subsidies affect enterprises' capacity decisions. The government can promote capacity sharing by subsidising enterprises. When β and capacity prices are both low, the government subsidises Enterprise 2. When the proportion of state-owned shares and capacity prices are high, the government subsidises enterprise 1. Under certain conditions, the government may subsidise enterprises to facilitate capacity sharing and improve social welfare.

The limitations of this study and suggestions for future research are as follows. First, this study considers only Cournot competition as a type of competition. If we continue to explore various types of competition, such as price and dynamic competition, we can reveal their impacts more comprehensively. Second, we only considered government intervention as a form of subsidy, and diversified government intervention methods are more in line with reality, which is an exploration direction for the future. Finally, in addition to price, realising capacity sharing may also be affected by technical and spatial factors guiding future research.

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Data Availability Statement

This article belongs to mathematical derivation which does not involve data availability.

Declaration of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article.

Notes

1. We have evaluated many numerical simulations and finally represent Proposition 5 and Corollary 2 by drawing two figures when $a=10$, $m=3$, $n=2$, $k_1=2$.

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