Chapter 4
A Decision-Making Model of Price Control for Administering Authority

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Abstract There are few quantitative studies on decision making of air ticket price control problem. In this paper we establish a game decision making model of price control for government by introducing two new factors: consumer's surplus (the public welfares) and the passenger load rate (LR). We get some interesting conclusions from modeling and discussion. The administering authority, CAAC (Civil Aviation Administration of China) is inclined to ignore the public welfares when setting a higher control price and the airlines are always inclined to disobey the control price of CAAC for achieving a higher passenger load rate and strengthening the competition edge. As a whole, the optimal strategy of CAAC is to set an inter-zone control price and the optimal strategy of airlines is to self determinate a price between the inter-zone prices. The reason of decision dissonance is that the cost evaluation of ticket pricing for the two players has tremendous difference.

Keywords Air ticket · Decision making · Game theory · Price control

4.1 Introduction

There are many studies on air ticket control, which are almost limited to qualitative analysis. Some use natural monopoly theory (Zhang 2005; Liu 2006) and some use welfare economics Liu (2002) to analyze the problem, and the result is almost similar that the government should release control to air ticket price and be unnecessary to intervene in operation or management of airlines (Liu 2002). Li and Deng (2003), Min and Yang (2003) conclude that the civil aviation of China has many pertinacious problems such as ticket price simplification, cut-throat

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competition and so on basing on an economics point of view, and analyze the reasons from all conceivable angles Li and Deng (2003), Min and Yang (2003). And there are also some studies using game theory to analyze the price control of CAAC to airlines (Mei et al. 2006; Yang and Zhang 2002), and the conclusions are that the control could cause lose of society welfare and ticket pricing should be marketization (Mei et al. 2006; Yang and Zhang 2002). Another train of thought is to advocate control, Zipping (Kang and Du 2006) approve of moderate control (Kang and Du 2006), Qiu (2001) points out that releasing control should be implemented gradually through comparing civil aviation development course of China with that of USA (Qiu 2001). Han (2000) indicates that the government should take some long-term measures to manage the special industry (Han 2000).

In a word, there're few quantitative studies on the problem and even in some quantitative literatures there are also some advancements to deserve promoting, for example, CAAC just emphasizes the economic revenue maximization (Mei et al. 2006; Yang and Zhang 2002). However, CAAC, as a government department, has a very important society function, which is protecting social welfare from being damaged. On the other hand, it is probably not appropriate to suppose that the airlines in China get into price war just for achieving economic profit maximization. The airlines may attach much more importance to increasing passenger load factor, market share, and strengthening their competitive edge. In reality, both CAAC and airlines might fall into prisoner's dilemma easily, and it's very difficult to get away the vicious circle (Wang 2004; Yang 2002). For these problems, we introduce consumer's surplus factor and passenger load rate factor into our game model to establish a ticket price control model for government.

4.2 Modeling

4.2.1 Hypothesis for Modeling

Hypothesis1: the game process is repetitive and limited, and the information for each other is imperfect. (For example, cost, intension and so on).

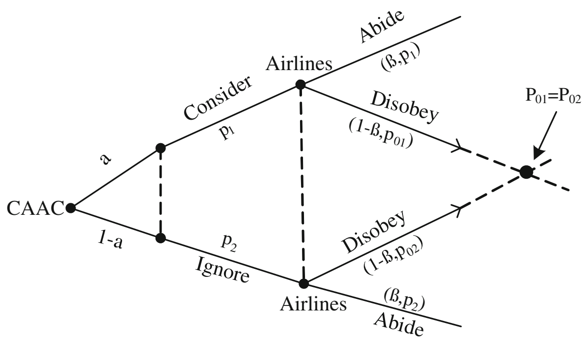
Hypothesis2: the CAAC and airlines in China have some common interests and close relations although the former is supervisor of the industry (for example, at aspects of finance and political achievements).

Hypothesis3: at present in China, the general ticket demand is price inelastic.

4.2.2 Construct Price Control Model

As one player of the game, CAAC has two pure strategies: one is "Consider the public welfare" (hereinafter called "Consider"), the lower price is p_1 and the

Fig. 4.1 Extensive game between CAAC and airlines



probability is α; another strategy is "Ignore the public welfare" (hereinafter called "Ignore"), the higher price is $p_2(p_2 > p_1)$, and the probability is $1 - \alpha$. Airlines as another player of the game also have two pure strategies: one is "Abide the price control" (hereinafter called "Abide"), the price is p_1 and the probability is β; another strategy is "Disobey the price control" (hereinafter called "Disobey"), the price they set will be $p_{0i}(i = 1, 2)$ that means the self-determinate price of airlines on condition that the control price is $p_i(i = 1, 2)$, and the probability is $1 - \beta$. Figure 4.1 shows the players' game decision tree with imperfect information, which means airlines could not distinguish whether the control price contains the public welfare or not, and CAAC also could not identify airlines' cost information and competition intention easily (shown as the broken line in Fig. 4.1).

The following is other some denotations used herein below.

TS	Social welfare equals to sum of *CS* and *ES*.$TS = CS + ES$
CS	Public welfare, also called customers' surplus
ES	Enterprise welfare, also called enterprise surplus
f(*p*)	Inverse demand function when the price is *P*, meanwhile, the equilibrium demand can be defined as $d(p)^k$, here d denotes conversion operator, k denotes price elasticity (absolute value)
LR(*p*)	Load rate of airlines when the ticket price is *p*, it's decreasing function of price *p*. It is supposed to be reasonable that airlines increase the passenger load rate and strengthen competitive edge by cutting down price
TCL	Transportation Capacity Limitation of airlines in a given period, it keeps stable during a determinate period of time and irrelevant with price
c_1	The unit cost of airlines estimated by CAAC
c_2	The unit cost of airlines estimated by airlines themselves

Figure 4.2 is payoff matrix of the two players. We define their payoff functions as bellows:

$\pi_{CAAC}(CA)$: The payoff of CAAC when CAAC considers the public welfare and airlines abide the price control. Essentially, the payoff equals to *TS*, which should contain *CS* and *ES*. And $CS = \int_0^{d(p_1)^k} f(p)dp$, here *d* denotes derivative symbol, $ES = (p_1 - c_1) \cdot d(p_1)^k$, so the payoff of CAAC is

	Abide (airlines)		Disobey (airlines)	
Consider (CAAC)	$\pi_{CAAC}(CA)$	$\pi_{ailines}(CA)$	$\pi_{CAAC}(CD)$	$\pi_{ailines}(CD)$
Ignore (CAAC)	$\pi_{CAAC}(IA)$	$\pi_{ailines}(IA)$	$\pi_{CAAC}(ID)$	$\pi_{ailines}(ID)$

Fig. 4.2 Payoff matrix of game players

$$\pi_{CAAC}(CA) = \int_0^{d(p_1)^k} f(p)dp + (p_1 - c_1) \cdot d(p_1)^k$$

$\pi_{airlines}(CA)$: The payoff of airlines when airlines abide the price control and CAAC considers the public welfare. Under the circumstances, the payoff of airlines is.

$$\pi_{airlines}(CA) = (p_1 - c_2) \cdot d(p_1)^k$$

$\pi_{CAAC}(CD)$: The payoff of CAAC when CAAC considers the public welfare and airlines disobey the price control. p_{01} is self-determinate price of airlines on condition that the control price of CAAC is p_1. Like $\pi_{CAAC}(CA)$, the payoff equals to *TS*, which should contain *CS* and *ES*. So

$$\pi_{CAAC}(CD) = \int_0^{d(p_{01})^k} f(p)dp + (p_{01} - c_1) \cdot d(p_{01})^k$$

$\pi_{airlines}(CD)$: The payoff of airlines when airlines disobey the price control and CAAC considers the public welfare. The payoff of airlines is

$$\pi_{airlines}(CD) = (p_{01} - c_2) \cdot LR(p_{01}) \cdot TCL$$

$\pi_{CAAC}(IA)$: The payoff of CAAC when CAAC ignores the public welfare and airlines abide the price control. Then the payoff just contains *ES*, so

$$\pi_{CAAC}(IA) = (p_2 - c_1) \cdot d(p_2)^k$$

$\pi_{airlines}(IA)$: The payoff of airlines when airlines abide the price control and CAAC ignores the public welfare. The payoff of airlines is

$$\pi_{airlines}(IA) = (p_2 - c_2) \cdot d(p_2)^k$$

$\pi_{CAAC}(ID)$: The payoff of CAAC when CAAC ignores the public welfare and airlines disobey the price control. p_{02} is self-determinate price of airlines on condition that the control price of CAAC is p_2. The payoff of CAAC is.

$$\pi_{CAAC}(ID) = (p_{02} - c_1) \cdot d(p_{02})^k$$

$\pi_{airlines}(ID)$: The payoff of airlines when airlines disobey the price control and CAAC ignores the public welfare. The payoff of airlines is.

$$\pi_{airlines}(ID) = (p_{02} - c_2) \cdot LR(p_{02}) \cdot TCL$$

4.2.3 Analyzing and Calculating for Model

According to the model above, the mixed strategy of CAAC is $\theta_1 = (\alpha,\ 1-\alpha)$, and the mixed strategy of airlines is $\theta_2 = (\beta,\ 1-\beta)$. The payoff function of CAAC can be expressed as.

$$\mu_1(\theta_1,\theta_2) = \alpha\begin{bmatrix} \beta\left(\int_0^{d(p_1)^k} f(p)dp + (p_1 - c_1)\cdot d(p_1)^k\right) + \\ (1-\beta)\left(\int_0^{d(p_{01})^k} f(p)dp + (p_{01} - c_1)\cdot d(p_{01})^k\right) \end{bmatrix} + (1-\alpha)\begin{bmatrix} \beta\left((p_2 - c_1)(p_2)^k\right) + \\ (1-\beta)\left((p_{02} - c_1)\cdot d(p_{02})^k\right) \end{bmatrix} \tag{4.1}$$

The first order condition of (4.1) is

$$\begin{aligned} \frac{\partial \mu_1}{\partial \alpha} &= \beta\left(\int_0^{d(p_1)^k} f(p)dp + (p_1 - c_1)\cdot d(p_1)^k\right) \\ &\quad + (1-\beta)\left(\int_0^{d(p_{01})^k} f(p)dp + (p_{01} - c_1)\cdot d(p_{01})^k\right) \\ &\quad - \beta\left((p_2 - c_1)\cdot d(p_2)^k\right) - (1-\beta)\left((p_{02} - c_1)\cdot d(p_{02})^k\right) \\ &= 0 \end{aligned}$$

So we can get β from $\frac{\partial \mu_1}{\partial \alpha} = 0$

$$\beta = \frac{(p_{02} - c_1)\cdot d(p_{02})^k - \int_0^{d(p_{01})^k} f(p)dp - (p_{01} - c_1)\cdot d(p_{01})^k}{\begin{array}{c}\int_0^{d(p_1)^k} f(p)dp + (p_1 - c_1)\cdot d(p_1)^k - \int_0^{d(p_{01})^k} f(p)dp - \\ (p_{01} - c_1)\cdot d(p_{01})^k - (p_2 - c_1)\cdot d(p_2)^k + (p_{02} - c_1)\cdot d(p_{02})^k\end{array}} \tag{4.2}$$

The payoff function of airlines can be expressed as:

$$\mu_2(\theta_1,\theta_2) = \beta\begin{bmatrix}\alpha\Big((p_1-c_2)(p_1)^k\Big)+\\(1-\alpha)(p_2-c_2)\cdot d(p_2)^k\end{bmatrix} + (1-\beta)\begin{bmatrix}\alpha(p_{01}-c_2)\cdot LR(p_{01})+\\(1-\alpha)(p_{02}-c_2)(p_{02})\cdot TCL\end{bmatrix} \tag{4.3}$$

The first order condition of (4.3) is

$$\frac{\partial\mu_2}{\partial\beta} = \alpha(p_1-c_2)\cdot d(p_1)^k + (1-\alpha)(p_2-c_2)\cdot d(p_2)^k - \alpha(p_{01}-c_2)\cdot LR(p_{01})\cdot TCL - (1-\alpha)(p_{02}-c_2)\cdot LR(p_{02})\cdot TCL = 0$$

So we can get α from $\frac{\partial\mu_2}{\partial\beta}=0$

$$\alpha = \frac{(p_{02}-c_2)\cdot LR(p_{02})\cdot TCL - (p_2-c_2)\cdot d(p_2)^k}{(p_1-c_2)\cdot d(p_1)^k - (p_2-c_2)\cdot d(p_2)^k - (p_{01}-c_2)\cdot LR(p_{01})\cdot TCL + (p_{02}-c_2)\cdot LR(p_{02})\cdot TCL} \tag{4.4}$$

According to Hypothesis1, the game is limited and imperfect information, airlines cannot distinguish whether the control price is set basing on public welfare or not, and CAAC also cannot pry about cost information and competition intention of airlines easily. In a limited period, CAAC sets a control price, if airlines intend to disobey, they are inclined to set self-determination price as p_0 uniformly, so $p_{01}=p_{02}=p_0$, which can be substituted into (4.2) and (4.4), then we can get new α and β.

$$\beta = \frac{-\int_0^{d(p_0)^k} f(p)dp}{\int_0^{d(p_1)^k} f(p)dp + (p_1-c_1)\cdot d(p_1)^k - \int_0^{d(p_0)^k} f(p)dp - (p_2-c_1)\cdot d(p_2)^k} \tag{4.5}$$

$$\alpha = \frac{(p_0-c_2)\cdot LR(p_0)\cdot TCL - (p_2-c_2)\cdot d(p_2)^k}{(p_1-c_2)\cdot d(p_1)^k - (p_2-c_2)\cdot d(p_2)^k} \tag{4.6}$$

4.3 Discussion

4.3.1 The Discussion of Optimal Decision of CAAC

Make some conversion to (4.5), β can be rewritten as:

$$\beta = 1 \bigg/ \left[1 + \frac{(p_2 - c_1) \cdot d(p_2)^k - (p_1 - c_1) \cdot d(p_1)^k - \int_0^{d(p_1)^k} f(p)dp}{\int_0^{d(p_0)^k} f(p)dp} \right]$$

, because $0 \le \beta \le 1$, so

$$\frac{(p_2 - c_1) \cdot d(p_2)^k - (p_1 - c_1) \cdot d(p_1)^k - \int_0^{d(p_1)^k} f(p)dp}{\int_0^{d(p_0)^k} f(p)dp} \ge 0,$$

and therefore $(p_2 - c_1) \cdot d(p_2)^k - (p_1 - c_1) \cdot d(p_1)^k \ge \int_0^{d(p_1)^k} f(p)dp$, and here.

$$(p_2 - c_1) \cdot d(p_2)^k \ge (p_1 - c_1) \cdot d(p_1)^k + \int_0^{d(p_1)^k} f(p)dp \tag{4.7}$$

The left part of (4.7) is $\pi_{CAAC}(IA)$, while the right part of (4.7) is $\pi_{CAAC}(CA)$, so (4.7) is $\pi_{CAAC}(IA) \ge \pi_{CAAC}(CA)$, CAAC has no motivation to improve and consider the public welfare, that is to say, CAAC is apt to maintain a higher industry price unilaterally rather than decreasing the control price for the public. Actually, CAAC has transferred the public welfare to enterprises and civil aviation industry by pricing at a higher level (Shaffer 2001). According to Hypothesis2, CAAC and airlines in China have many common interests and close relations, not only the finance aspects, but also the politics achievements of CAAC have to rely on development and stability of the civil aviation industry. At this point of view, the result is corresponding to Hypothesis2, and also corresponds with the reality.

4.3.2 The Discussion of Optimal Decision of Airlines

Because the ticket demand is price inelastic (Hypothesis3), and $p_1 < p_2$, for parameter α, it is supposed to follow the restrictions as bellow:

$$\begin{cases} \alpha = \dfrac{(p_0 - c_2) \cdot LR(p_0) \cdot TCL - (p_2 - c_2) \cdot d(p_2)^k}{(p_1 - c_2) \cdot d(p_1)^k - (p_2 - c_2) \cdot d(p_2)^k} \\ (p_1 - c_2) \cdot d(p_1)^k - (p_2 - c_2) \cdot d(p_2)^k < 0 \\ 0 \le \alpha \le 1 \end{cases} \tag{4.8}$$

Referring to (4.8), we get the calculation result:

$$(p_1 - c_2) \cdot d(p_1)^k \le (p_0 - c_2) \cdot LR(p_0) \cdot TCL \le (p_2 - c_2) \cdot d(p_2)^k \tag{4.9}$$

The middle part of (4.9) is $\pi_{airlines}(CD)$, and also $\pi_{airlines}(ID)$, the left part of (4.9) is $\pi_{airlines}(CA)$ and the right part of (4.9) is $\pi_{airlines}(IA)$. So (4.9) can also be rewritten as:

$$\pi_{airlines}(CA) \le \pi_{airlines}(CD) = \pi_{airlines}(ID) \le \pi_{airlines}(IA)$$

Airlines cannot observe whether CAAC has considered the public welfare or not when setting control price, and obviously the self-determination price p_0 could produce more profits than the lower control price p_1 could, and theoretically speaking, abiding a higher control price p_2 could get more profits than self determining price p_0 could, but there may be two reasons at least to make them depart from the "optimization path": one is that airlines cannot stand a very low passenger load rate because of a higher price, which is a big waste of resources; another is that when a competitor reduce the price, the others have to fallow the decreasing price strategy, or they may suffer much more lost, which results from product homogeneity of air transportation in China.

4.3.3 The Discussion of Decision Dissonance of Two Players

Basing on the discussion *A*, the optimal strategy payoff of CAAC is $(p_2 - c_1)\cdot d(p_2)^k$, of which the first order condition is $\frac{\partial\left[(p_2-c_1)\cdot d(p_2)^k\right]}{\partial p_2} = 0$, so $p_2 = \frac{k}{1+k}c_1$; Basing on the discussion *B*, the optimal strategy payoff of airlines is $(p_0 - c_2)\cdot LR(p_0)\cdot TCL$, of which the first order condition is $\frac{\partial[(p_0-c_2)\cdot LR(p_0)\cdot TCL]}{\partial p_0} = 0$, so $p_0 = c_2 - \frac{LR}{LR'}$, LR' is the derivative of $LR(p)$ at $p = p_0$, $LR(p)$ is decreasing function of price p, so $LR' < 0$, simultaneously $0 < LR(p) \le 1$, so $p_0 = c_2 - \frac{LR}{LR'} > c_2$. Then the restriction condition is

$$\begin{cases} p_2 = \dfrac{k}{1+k}c_1 \\ p_0 = c_2 - \dfrac{LR}{LR'} > c_2 \\ p_2 > p_0 \end{cases}, \text{ so } \frac{k}{1+k}c_1 > c_2, \text{ because}$$

$0 < \frac{k}{1+k} < 1$, the calculation result is $c_1 > c_2$. CAAC sets the control price basing on the cost evaluation of c_1, which is usually the average cost of civil aviation industry. While airlines self determinate competitive price basing on the cost evaluation of c_2, which is probably the margin cost of the company. The tremendous difference between c_1 and c_2 causes decision dissonance of the two players. So as long as $p_0 > c_2$, airlines always have the motivation of disobeying and cutting down control price.

4.4 Decision Making

For CAAC, the optimal strategy is setting a higher control price without considering the public welfares because it has many underlying common interests with airlines and the civil aviation industry, for example, at aspects of finance and political achievements. But airlines are always inclined to disobey the control price and get into price war. The reason is that airlines in China have to face furious competitions after the so called "deregulation", while the property rights of leading airlines still belong to administrative departments. For this kind of natural monopoly industry of civil aviation, fixed costs are very high while the margin costs are very low, so for airlines there always has been pressure and space of cutting down price. And we have proved that when the self-determination price p_0 is lower than the control price p_2, airlines could become more competitive such as getting a higher passenger load rate, a bigger market share and so on. However, when $p_0 < c_2$, (it is possible because of the unusual structure of property rights) the air transport market will be in disorder and the whole industry welfares will be seriously damaged.

And then CAAC has to set a lower boundary for the control price to prevent this phenomenon form happening, so that the self-determination price of airlines cannot be under the lower boundary of control price on any account.

p_1 is a lower control price when CAAC considers the public welfares, when $p_0 > p_1$, the airlines can get excess profit, or else they will go into red. So the optimal strategy for CAAC is setting an inter-zone control price, for example $[p_1, p_2]$, and the optimal strategy for airlines is self-pricing between p_1 and p_2. Basing on the decisions above, CAAC could get balance among the industry welfares, healthy development of the market and the public welfares, airlines could get balance between the profits and competitive edges. Lastly it is necessary to note that the final decision makings of the two players are both based on the present special structure of property rights of civil aviation in China, which could not be reformed or changed in a short time period.

4.5 Conclusion

Unlike many qualitative analyses on air ticket price control problem, we build a quantitative price control model based on game theory by introducing two new decision factors: *CS* (customer's surplus, also called the public welfares) and LR (passenger load rate). Through modeling and discussing, we get some interesting results and conclusions: CAAC is inclined to ignore the public welfares when setting the control price of air ticket, which may be a higher price p_2, whereas, airlines are always inclined to disobey the control price of CAAC for achieving a higher passenger load rate and strengthening the competition edge, which may be a self-determination price p_0, and $p_1 < p_0 < p_2$, where p_1 is a lower control price when CAAC considers the public welfares.

At present, main airlines of China have very special structure of property rights, that is to say airlines face dual pressures of administrative regulations and market competitions, which may cause airline's dumping price for market shares and competition edge, even may lead to $p_0 < c_2$, so CAAC has to define a lower boundary for the control price to prevent this kind of vicious competition behavior. As a result, CAAC sets an inter-zone control price for achieving to keep enough industry welfares, ensure healthy development of the civil aviation industry and consider moderate public welfares. And when $p_0 \in [p_1, p_2]$, airlines can get balance between the revenues and competition edge, and CAAC can also get balance between the industry welfares and the public welfares.

The reason of decision dissonance between the two players is tremendous difference of cost evaluation for air ticket pricing ($c_1 > c_2$, shown as discussion *C*). c_1 is the cost evaluation of CAAC, usually an average cost of the whole industry, and c_2 is the cost evaluation of airlines, usually a margin cost of the product. In terms of economics and competitions, as long as $p_0 > c_2$, airlines are always inclined to disobey and decrease the control price for a higher passenger load rate, i.e. for competitive edge.

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