SYSTEM DYNAMICS BASED SIMULATION MODELLING
FOR AIRPORT REVENUE ANALYSIS

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ABSTRACT

Using a System Dynamics (SD) approach, this PhD research examines the relationships between airports and airlines, with the objective of optimising airport revenue. In the context of airport privatisation, airline deregulation and internationalisation; airport managers need to make a wide range of policies changes and explore new business strategies to increase their revenues.

Airports are multi-sided enterprises where numerous agents interact, and the revenues are affected by the interrelationships between the parts: airport, airlines, passengers, and government. The SD model captures the system of relationships among the multiple aspects of the airport into five modules: Demand (and Competition), Traffic Volume, Airport Aeronautical Revenue, Non-Aeronautical Revenue, and Capacity. This structure is based on the two types of activities undertaken by an airport: i) the traditional, aeronautical operations; and ii) the non-aeronautical (commercial/concession) operations. The SD model compares the airport revenue systems between two middle size airports with different market power, under different regulation and competition conditions: Perth, Australia and Nanjing, China.

The model is built at two levels: at the high-level, various regulation regimes and policies can be explored; at the low-level, the model can simulate what-if scenarios to explore the impact of different policies like price-making or agreements with airlines, on airport revenue and market responses (e.g. high-speed rail competition). The model makes possible the investigation of the actions taken by airlines or other related agents, including government, as a permanent feedback to the airport’s decisions.

Based on the final model simulations, it is concluded that government regulation is essential for an airport without competition from other modes because the airport
revenues are positively related to the airport charge rate. When a government decides the price-cap for an airport (e.g. Nanjing Airport), this type of regulation can hinder rather than provide an incentive to the airport to increase its capacity, through limited cost recovery mechanisms. On the other hand, under light-hand regulation (e.g. Perth Airport), the airport has the flexibility to adjust airport charges upon new developments; therefore, it is crucial for the government to assess whether new investments are necessary to facilitate an airport capacity increase. Negotiation between airports and airlines is also essential for “optimising” airport and airline revenues.

For airports, it is practical to apply different charge rates on different routes to optimise revenue. Generally, airports choose to apply higher charge rates when there is no competition. However, under competition with other modes, the airport could adopt the different strategy of lowering charges, to enable airlines in turn to reduce airfares. If there are low-cost carriers in the market, the airport will differentiate between full-service airlines and low-cost carriers by offering lower airport charges to the latter, to encourage them to offer lower airfares and higher frequencies.

The model shows that high-speed rail (HSR) competition is likely to substantially erode the revenues of airports and airlines due to its lower prices and higher frequency, especially on shorter distance routes. To compensate, airports and airlines are encouraged to work together to offer similar competitive services or distinct benefits for travellers (e.g., better connections, flexibility, and reduced time on ground). Multimodal bundles could also be considered on some routes as potential strategies to secure demand.

Similarly, anticipating the changes triggered by low-cost carriers (LCC); airport and airlines could better adapt by discriminating across market segments and targeting them with appropriate measures.
Still, as shown by the two cases, the responses depend on the local conditions (market power, airport charge value.). This highlights the importance of the model that can easily be applied as a decision support system (DSS) to explore potential impacts of various regulation policies and competition. This is what this research aims to deliver: an expanded platform that can be further used to investigate various conditions – by incorporating costs and examining profits; and accounting for passenger benefits, disadvantage and preference.
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GLOSSARY OF TERMS/ABBREVIATION

APP: Airline Pass Percentage (proportion changes in the airfares after the airport charge its charges)

ASK: Available Seat Kilometre

BITRE: Australian Bureau of Infrastructure, Transport and Regional Economics

CAAC: Civil Aviation Administration of China

CLD: Causal Loop Diagram

DEA: Data Envelopment Analysis

FSA: Full Service Airline

HSR: High Speed Rail

IATA: International Air Transport Association

NKG: Nanjing Airport

LCC: Low Cost Carrier

O-D: Original- Destination

PDF: Probability Density Function

SD: System Dynamics

SFD: Stock and Flow Diagram

SLF: Seat Load Factor
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STATEMENT OF CANDIDATE CONTRIBUTION

This thesis contains published co-authored work. The bibliographical details of the work and where it appears in the thesis are outlined below:


Part of the published work listed above is included in Chapter 5 of my thesis.
CHAPTER 1 INTRODUCTION

1.1 Motivation

With the increasing trend towards airport commercialisation and privatisation, airports have been experiencing more and more financial pressure to become financially self-sufficient and less reliant on government support (Baker and Freestone, 2010; Graham, 2009; Gillen, 2011; Fu et al., 2011; Fuerst et al., 2011). In this situation, airports are increasingly being operated like businesses. These changes have not only weakened the public utility function of airports, but also required airports to increase their revenue and reduce costs.

In order to increase revenue, airport managers are encouraged to make a wide range of policy changes and explore new business strategies as well. Since the airport is a multi-sided platform where numerous agents interact, the airport revenue system involves many components: the airport, the airlines, the passengers and the government. Airport revenue is affected by these interrelationships and airports’ policies or strategies are influenced by a range of direct and indirect forces; e.g. various regulations can prevent airport managers from increasing prices, even if the airports have been privatised. As the airport business environment goes through numerous dynamic changes (e.g. airport privatisation and airline deregulation, low-cost carrier emergence, high-speed train competition); the challenge now faced by airports is to increase their revenue by addressing all their dyadic relationships including airport-airlines, airport-government and airport-passengers.

Airports can respond quickly and effectively to these dynamic and global changes and identify the key revenue growth strategies by using a partnership approach cooperating with all the agents operating businesses associated with the airport. The
whole structure of the airport revenue system and all the relationships between airports and their partners need to be investigated. In addition, understanding the implications of changing the airport revenue system is fundamental for guiding and informing policy decisions for the airports, airlines and government within different market situations.

This dissertation views airports as platforms where airlines, passengers and companies interact. It is this network of relationships that affects the total revenue of the airports that is considered, in order to explore the interactions governing the airport operation and identify how the airport can optimise its revenues under specific market structure, airport-airline relationships, and different regulatory schemes.

1.2 Background and Key Issues in the Airport Revenue System

The airport revenue system is one that has to consider the interaction of numerous agents: the airport, the airline, passengers and the government. Such relationships are included in Figure 1.1, which presents the basic structure of the airport revenue system.

An airport derives its revenue from two types of business: i) the traditional, aeronautical operations; and ii) the non-aeronautical (commercial/concession) operations (Ivaldi et al., 2011). The former refers to aviation activities associated with runways, aircraft parking, ground handling, terminal check-in, security, passport control and gate operations (e.g. aircraft landing fees, aircraft parking and taxiway charges, passenger terminal and facility charges); whereas the latter refers to non-aeronautical activities occurring within terminals and on airport land including terminal concessions (e.g. duty-free shops, restaurants, entertainment facilities.), car rental, car parking and other income from activities on airport territory (e.g. land rental). The landing and terminal fees are core components of aeronautical revenue, while the trading revenue and the ground transport revenue account for the majority of the non-aeronautical revenue.
The transformation of airport from a transport facility to more broadly based activity centre is driven by the rise in passenger volumes, the shift of airport ownership and airport profit-seeking (Baker and Freestone, 2010). Over the last twenty years, the commercial revenue has become more important in the airport sector. For example, the Air Transport Research Society’s global airport performance benchmarking project (ATRS, 2006) reports that most of the major airports around the world generate anywhere between 45% and 80% of their total revenues from non-aeronautical services, a major portion of which is the revenue associated with the passenger volume of the airport (e.g. trading, car parking).

Figure 1.1 shows that the total airport revenue is primarily calculated as the sum of the aeronautical revenues paid by the airlines and the non-aeronautical revenues obtained mainly from passengers in the terminal. The airport charges airlines an aeronautical fee based on traffic volume: flights and/or passengers. Therefore, it is clear that the passenger volume affects both aeronautical and non-aeronautical revenues. In general, lower airfares are expected to lead to higher passenger volumes. However, the airfare is affected by not only the airline policy (e.g. airline competition), but also by the airline operation costs, of which the airport aeronautical charges may represent a substantial part. On the other hand, the traffic volume is also influenced by the market power of the airport. For example, some airports with low market power would face competition from other airports and other transport modes, like HSR or buses/coaches. In this case, the airports and the airlines both prefer to negotiate an agreement for sharing benefits. If the airport provides lower aeronautical fees to attract more airlines and passengers, this will also have a positive effect on retailers and ground transport demand in the airports, with non-aeronautical revenues expected to grow accordingly. Thus, there is an incentive to restrain aeronautical charges in order to increase the non-aeronautical revenues (Zhang and Zhang, 1997; Gillen and Morrison, 2003; Kratzsch and Sieg, 2011).
Figure 1.1 Relationships in the Airport Revenue System
From Figure 1.1, it can be observed that the airport does not decide alone the aeronautical charge; this is also regulated or monitored by the government. In some airports the government may prescribe the approach for deriving the aeronautical charge, in others it may enforce an upper limit, or in many other airports the government plays only a surveillance role.

Figure 1.1 illustrates the relationships among airport traffic volume, airport charge, airline passenger demand, airfares and airport revenues. Within this structure, the situations and issues underlying the airport revenues can be analysed in four aspects: government; price regulation; airport-airline relationships and competition with other modes. These are described in greater detail in Sections 1.2.1-1.2.4.

1.2.1 Ownership of Airports

Privatisation started with some UK airports in 1987 and more airports have been privatised or partially privatised since, especially in Europe, Australia and New Zealand. However, the move to private ownership has been slower than in other industries. In many airports, governments have applied partial, rather than full privatisation. The main ownership structures are listed in the Table 1.1.

Table 1.1 Structure of Ownership

<table>
<thead>
<tr>
<th>Ownership structure</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government owned/operated</td>
<td>US, Spain, Singapore, Finland, Sweden</td>
</tr>
<tr>
<td>Government owned, privately operated</td>
<td>US (via contracts), Chile</td>
</tr>
<tr>
<td>Independent not-for-profit corporations</td>
<td>Canada</td>
</tr>
<tr>
<td>Fully private for-profit via IPO (Initial Public Offering) with stock widely held</td>
<td>UK (originally BAA)</td>
</tr>
<tr>
<td>Fully private for-profit via trade sale with share ownership tightly held</td>
<td>Australia, New Zealand</td>
</tr>
<tr>
<td>Partially private for-profit with private controlling interest</td>
<td>Denmark, Austria, Switzerland</td>
</tr>
<tr>
<td>Partially private for-profit with government controlling interest</td>
<td>Hamburg Germany, France, China, Japan</td>
</tr>
</tbody>
</table>

With the increasing number of airports privatised, there has been a transition from positioning airports as public utilities to being multi-product firms, delivering airside services to a range of airlines and terminal retail and access services to passengers. This has led to airport diversification of their customer and revenue streams, resulting in airports negotiating with their partners with varying degree of power. Additionally, as the private airports use their market power or reduce the aeronautical charges to gain more non-aeronautical revenues by attracting more passengers, there is a continuous debate whether regulation is necessary or not.

1.2.2 Airport Regulation and Pricing

Aeronautical pricing is usually regulated by the government. The form of regulation influences pricing behaviour and airport revenues. Although various forms of regulation have been adopted by different countries around the world, the most widely used regulatory regimes are: (a) price-cap regulation; (b) rate of return regulation (cost-based); (c) light-handed regulation (price monitoring and threat of regulation) (Adler et al., 2015; Gillen, 2011; Oum and Fu, 2008; Phang, 2016; Zhang and Czerny, 2012).

**Price-Cap Regulation:** Price regulation usually takes the form of a price-cap applied to revenues derived from airport charges per passenger. Price cap regulation adjusts the airport’s prices according to the price cap index that reflects the overall rate of inflation in the economy and the ability of the airport to make efficiency gains relative to the average commercial operator in the economy.

**Rate of Return / Cost-based Regulation:** This benchmarks the profitability of regulated activities to the average of reference airports or businesses; that is, the price is calculated from efficient costs of production plus a market determined rate of return on capital investment.
**Price Monitoring and Threat of Re-regulation:** These are currently implemented in Australia and New Zealand. ‘The regulators use a trigger or "grim strategy" regulation where a light-handed form of regulation is used until the subject firm sets prices at unacceptable levels or earns profits deemed excessive or reduces quality beyond some point and thus, triggers a long-term commitment to intruding regulation.’ (Gillen, 2011: 7).

In light of there being two main sources of airport revenues, airport regulation has varied in another dimension: (1) single-till; and (2) dual-till.

**Single-till:** Both aeronautical and commercial revenues and costs are considered in determining the level of aeronautical charges. There is often a cross-subsidy for aeronautical services from revenues arising from commercial activities.

**Dual-till:** This separates aeronautical from non-aeronautical functions. It determines the level of aeronautical charges by considering aeronautical revenues and costs only. The single-till and dual-till distinction can be applied to both price-cap and rate of return regulation regimes.

Aeronautical charges are likely to be set at a higher level under a dual–till approach, compared to a single-till approach where cross-subsidisation from non-aeronautical revenues will help offset some of the costs of the aeronautical services. Lower charges will attract more airlines and passengers, which may lead to higher commercial revenues. However, the obvious question is regarding how low airport charges should be set in order to optimise the total airport revenue. Another problem with using a single-till approach in a capacity-constrained airport is that the airport may become over congested.

When making the price-policy, the airport must take into account the effect of pricing on its aeronautical and non-aeronautical revenues. How to decide an appropriate price under current regulation is always a concern for the airport. On the other hand, when
the government decides on the regulation regime, it should consider - at the macro-level - the interests of all parties involved, including airports, airlines and passengers.

1.2.3 Airport-Airline Relationships

With the commercialisation of airports, the relationship between airport and airlines has also changed significantly and become more complex. An important characteristic is its “vertical structure”: airports reach their final customers directly - via passenger terminals - and indirectly through airlines. An airport is an input provider to the airlines that typically possess market power and compete with each other in the air travel market. Airports maximise opportunities to increase their income from commercial revenues to compensate for any reduction in aeronautical revenues.

Despite some conflicting interests, especially with regard to aeronautical service charges, airports continue to develop close relationships with airlines in order to increase their non-aeronautical revenues. This is not surprising considering that the terminal customers are transported by the airlines.

The following types of relationships are often observed in practice (Fu et al., 2011b):

**Signatory airlines.** Carriers who sign a master use-and-lease agreement are awarded the so-called “signatory airline” status. Those airlines become eventual guarantors of the airport’s finance. This reduces the uncertainty over future airport revenues, and thereby allows the airport to reduce financing costs when securing long-term bank loans (Oum and Fu, 2008). In return, signatory airlines are given varying degrees of influence over airport planning and operations, including slot allocation, pricing, terminal usage, and exclusive or preferential facility usage. This arrangement is common practice in US and Australia (Barbot, 2009).
**Airlines owning or controlling airport facilities.** Some airlines hold shares in airports (e.g., Lufthansa and FMG in Munich) or directly control airport facilities (e.g., Qantas in Sydney, Melbourne and Perth). In addition, some logistics carriers made investments in their operating hubs. For example: UPS, FedEx, and DHL in several Chinese airports (Fu et al., 2011b).

**Long-term usage contract.** Many airlines hold long-term contracts with airports, giving them the rights to using facilities, such as gates, regardless of usage. In recent years, the Low Cost Carriers (LCCs) have organised this type of long-term contract with airports. Many secondary airports offer LCCs favourable use terms in order to attract their traffic (Fu et al., 2011b).

**Revenue sharing between airports and airlines.** Increasingly, airports have relied on concession services to bring in more revenue. Because these operations depend on the passengers carried by the airlines, an increasing number of airports have started to internalise this externality by sharing their revenue with the airlines and thereby giving them incentives to bring in more passengers (Zhang et al, 2010).

In most situations, the government monitors the airport-airline relationships that will have effects on both sides and on market competition. The airport cooperates with the airlines according to different arrangements that affect the airport revenues, both aeronautical and non-aeronautical (e.g. sharing concession revenue with the airline and negotiating the landing fee).

The rise of the low cost carriers (LCC) has brought dramatic growth in passengers to some airports. Compared with full service airlines (FSA), LCCs are featured as low airfare, “no-frills” carriers (not offering complimentary in-flight services), with high utilisation of their aircraft and crew, operating a single aircraft type and service class, on point-to-point and short/medium haul route structures via secondary airports (Gudmundsson, 1998; Graham, 2013). Airports need to understand the value of growth
in LCCs, while at the same time protecting their current airline partners’ passenger numbers and routes from the additional competition. The airport needs to consider the extent to which revenue losses from FSAs can be made up with LCCs via lower aeronautical charges. How to encourage airline competition to a level that is sustainable and profitable, through an airport-airline agreement/price scheme, is now an essential question for airports.

1.2.4 Competition with Other Transport Modes

Despite all the challenges facing the airport, the air transport industry as a whole must also recognise the threat of substitution by other modes of transport including rail, car and bus. In recent years, High-Speed Rail (HSR) with a speed of over 300km per hour has been introduced globally, due to its comfort, reduced generalised cost and environmental benefits. HSR emits less CO₂ than cars and airplanes. In countries such as France, Germany, Japan, Korea and China, HSR has gained a leading market share in the medium to long-distance transport markets (Fu et al., 2012; Haas, 2014).

The launch of HSR has enabled rail transport to obtain significant market share on routes where time sensitive passengers would previously have travelled by air. Besides the lower price, HSR offered faster city-to-city journey times, as well as a better travelling environment for the passenger. However, the expansion of low-cost airlines means that on some routes prices for air transport are now similar to or below the price of rail transport, which could have the potential to reverse the “switch” in the market share. To compete with other transport modes, airports need to cooperate with airlines in order to achieve a win-win strategy. In this situation, the main problem for the airport is how to provide competitive conditions to the airlines, so that they can attract more passengers to beat the common competitor (e.g. HSR).
1.2.5 Summary

Since multiple agents interact airport revenue is affected by type of regulations, relationship between airlines and airports, competition between air and other modes, as well as airline competition. Therefore, the airport revenue problem needs to be examined at various levels. Here, two key levels are considered: airport-government level and airport-airline level. Accordingly, the following questions are addressed in this research:

1. What is the long-term impact of price regulation on the revenues of airports with different market power and what are most important influencing factors in each price regulation regime?

2. What is the effect on the airport revenue of the competition between air transport and HSR and how do airports and airlines respond to compete with it?

3. What is the impact of LCCs on airport revenue?

1.3 Research Objectives and Contribution

Given the motivation and main research questions presented in previous sections, the objectives of this research can be summarised as: (1) to investigate the impact of price regulation on airport revenue in order to find out how the airport makes price-related decisions to optimise its revenue under different situations; (2) to investigate the impact of HSR on airport revenue to explore how the airport could provide a varying price scheme to the airlines and get “win-win” outcomes under different market structures; (3) to investigate the impact of LCCs on airport revenue to better understand how the airport could manage their relationships with LCCs to optimise its revenue.

As indicated, this study views airports as platforms where airlines, passengers and companies interact, and how this network of relationships affects the total revenue of the airports. A simulation model has been developed to explore the interactions governing
the airport operation to identify how the airport can optimise its revenues under specific market structures, airport-airline relationships and different regulatory schemes.

This research provides methodological, practical and managerial contributions, detailed as follows:

- It provides a generic system dynamics simulation model to analyse the main factors influencing airport revenue and evaluate their interrelated effects, a tool that can be applied easily as a decision support system (DSS) to explore potential impacts of various regulation policies and competition, with a model built at two levels: high-level (Chapter 4) and detailed/low level (Chapters 5-7);
- It compares the airport revenue systems between airports with different market power under different conditions, based on the data extracted from two case studies for middle-size airports in Perth, Western Australia and Nanjing, China, each with a similar scale of operation;
- It offers a guide to policy-making with respect to airport pricing and airport operation derived from a better understanding of the effect of multiple interactions on airport revenue and provides recommendations for combining measures (including pricing and arrangements with airlines), which can optimise airport revenue.
- It offers an expandable modelling structure, which creates the possibility to investigate various conditions such as the incorporation of costs, maximisation of profits and passenger benefits and disadvantages.

1.4 Main Findings

Based on the final model simulations, it is concluded that government regulation is essential for any airport, including those without competition from other modes, because
the airport revenues are positively related to the airport charge rate. When a government decides the price-cap for an airport (e.g. Nanjing Airport), this type of regulation can hinder rather than provide an incentive to the airport to increase its capacity due to limited cost recovery mechanisms. On the other hand, under light-hand regulation (e.g. Perth Airport), the airport has the flexibility to adjust airport charges upon new developments; therefore, it is crucial for the government to assess whether new investments are necessary for an airport to increase its capacity. Negotiation between airport and airlines is also essential for “optimising” airport and airline revenues.

For airports, it is practical to apply different charge rates on different routes to optimise revenue. Generally, airports choose to apply higher charge rates when there is no competition. However, when in competition with other modes, the airport could adopt a different strategy of lowering charges, to enable airlines to in turn reduce airfares. If there are LCCs in the market, the airport will differentiate between full-service airlines and LCCs by offering lower airport charges to the latter, to encourage them to set lower airfares and higher service frequencies.

The model shows that HSR competition is likely to substantially erode the revenues of airport and airlines due to lower prices and higher frequency, especially on shorter distance routes. To compensate, airports and airlines are encouraged to work together to offer similar competitive services or distinct benefits for travellers (e.g., better connections, flexibility, and reduced time on the ground). Multimodal bundles could also be considered on some routes as potential strategies to secure demand.

1.5 Structure of the Thesis

The subsequent parts of the thesis are organised as follows. Chapter 2 provides an overview of previous relevant studies related to effects on airport revenue including the
impact of differing ownership and regulation, the impact of the market structure of the airport, as well as the impact of the airport-airline relationships. A current gap in the literature is identified and then an indication provided as to how this research seeks to remedy the shortage of scholarship in the area. Chapter 3 describes the methodology applied, system dynamics (SD), and how the required data is collected. Chapter 4 presents the structure of a base SD high-level model to examine the long-term impact of price regulation on the airport revenue at the airport-government level, under different market conditions. Two cases: Perth and Nanjing airports, are compared in this chapter. The high-level model built is then expanded into a low-level model in Chapter 5 by incorporating the airport-airline interrelations, to explore how the airport makes price decisions to optimise its revenue at route level. Chapters 6 and 7 demonstrate the SD model at airport-airline level in an application to Nanjing Airport, to examine the effect of HSR and LCCs on airport revenue. All the scenario simulations are illustrated and discussed in Chapters 4-7. The concluding chapter summarises all the findings and offers directions for further study. All the equations applied in constructing the SD models are listed in the Appendix A1.
CHAPTER 2 LITERATURE REVIEW


Four main themes have been identified in addressing airport revenue and operation: a) airport revenue and pricing; b) the effect of the governance structure on airport revenue; c) the impact of market structure on airport revenue; and d) the effect of airport-airline relationships on airport revenue.
2.1 The Airport Revenue and Airport Pricing

Basso and Zhang (2008) reviewed analytical models of airport pricing from 1987 to 2007 and classified the literature (empirical papers excluded) into two approaches, the traditional and the vertical structure approach. In the traditional stream, the demand for airports depends on airport charges and congestion costs of both passengers and airlines, excluding the airline from the model (Czerny, 2006; Lu and Pagliari, 2004; Oum et al., 1996, 2004; Zhang and Zhang, 1997, 2001a, b, 2003). In the vertical approach, the demand for airport service is not only dependent on the airport, but also on the airlines, which have market power; the airline being considered an “input” for the airport when the airport makes any decision (Brueckner, 2002; Pels and Verhoef, 2004; Raffarin, 2004; Zhang and Zhang, 2006). In particular, more recent airport research has largely taken on the vertical structure (Czerny and Zhang, 2014, 2015; Zhang and Czerny, 2012).

2.1.1 Types of Revenues

To date, a substantial part of the literature regarding airport revenue emphasises the aeronautical activities, while few have focused on the non-aeronautical sources. Although this is not surprising, given the role of aeronautical activities in airports’ operation, the non-aeronautical revenues should receive more attention, especially where they account for a big chunk of total airport revenues. Because of the growing importance of non-aeronautical activities, airports should explore more systematically how to optimise their joint aeronautical and non-aeronautical revenues (Baker and Freestone, 2010; Castillo-Manzano, 2010; Fasone et al., 2016; Francis et al., 2004; Gillen and Mantin, 2014; Graham 2009; Kratzsch and Sieg, 2011; Orth et al., 2015; Zhang and Zhang, 1997; Zhang et al., 2010, 2012).
A number of authors have shown that there is a relationship between aeronautical and concession services. This means that the aeronautical charge can impact both the passenger demand and the concession demand. Vice versa, the level of non-aeronautical revenue might also have an impact on the aeronautical charge (Starkie, 2008; Czerny, 2013; Gillen and Mantin, 2014). Depending on the type of agreement with airlines, airports can make use of this source of revenue to cross-subsidise aeronautical revenue. Starkie (2001, 2002) argued that profit-maximising airports are unlikely to exploit their market power by increasing aeronautical charges, when complementary commercial activities exist and provided a graphical analysis to demonstrate that airport concession services can reduce the private aeronautical charge. This impact of non-aeronautical revenue on decreasing the aeronautical charge is supported by many scholars, including Zhang and Zhang (2003), Oum et al. (2004), and Czerny (2006). Similarly, Gillen and Morrison (2003) found that profit-maximising airports have every incentive to stimulate revenue via lower charges on the aeronautical side, if airports are not capacity constrained. This was supported by a more recent research by Kratzsch and Sieg (2011), who presented an equilibrium model and provided proof that landing fees are lower if the degree of complementarity between aviation and non-aviation is higher, at an uncongested private airport with market power. It complemented the finding of Zhang and Zhang (2010) by revealing that the incentive to restrain landing fees is true for the case of non-atomistic carriers. Choo (2014) investigated the factors affecting airport aeronautical charges with a panel dataset based on 59 United States airports during 2002 to 2010. The study found two main factors correlating to aeronautical charges: airport unit cost and non-aeronautical revenue. This may be the first empirical study confirming a strong evidence of cross-subsidisation from non-aeronautical revenue to aeronautical charges. Therefore, there is a common understanding that the non-aeronautical revenue could reduce the private airport’s incentive to charge high aeronautical prices (Zhang and
Czerny, 2012). Nevertheless, Czerny (2013) and Gillen and Mantin (2014) further pointed out that this private behaviour will lead to excessive congestion because of the more passengers brought by a lower aeronautical charge. Another most recent study (Fasone et al., 2016), based on German airports, also indicated that a higher number of passengers may negatively affect non-aeronautical revenues because there is a potential conflict between the $ shopping revenue per passenger and per square metre at the terminal when the number of passengers increases substantially.

As Fuerst et al. (2011) stated, “the relevant determinants [of airport revenue] are potentially as numerous as the airports for which the information is available” (p. 278), supporting the argument that the total airport revenue problem is unique for each airport and that the revenue and pricing are decided by the interrelationships among numerous factors in the government-airport-airlines system. Both aeronautical and commercial revenues need to be included in the calculations of the airport landing charge, whether supervised by the government or not.

A step forward in approaching airport revenue as a complex system was made by Ivaldi et al. (2011). They modelled the airport as a two-sided platform (Gillen, 2009, 2011) where airlines and passengers interact, and the airport internalises the network externalities arising from both types of demand. Their nested logit model, applied to secondary data collected on US airports and airlines, showed that increases in both ticket fares and/or parking fees diminish the passenger demand, and that passengers prefer frequent departures but they do not like congestion at the airport. These findings support the two-sided view and the need to incorporate the feedback from one side to another. Moreover, the pricing schemes showed that airports can cross-subsidise between the two types of activities, taking account of their elasticities. Finally, Ivaldi et al. (2011) found that many airports do not maximise profits, as it is suggested by the charges below marginal costs of aeronautical and non-aeronautical operations.
2.2 The Impact of Government Structures on the Airport Revenue

Since 1978, the aviation system has been subject to significant changes. What it is observed now is that with the intention to reduce government involvement, minimise costs, and maximise productivity, a wave of airport privatisations began in the late 1980s. As already indicated, airports are for the most part run as modern businesses, along commercial guidelines. There has been a transition from positioning airports solely as public utilities towards being firms delivering non-aeronautical services to airlines, terminal retail and access services to passengers, plus additional ancillary services. The changes of ownership and incentives encourage airports to maximise their profits. Since some airports possess considerable market power, there is a risk they would use their position to unjustifiably raise prices and achieve excessive returns. In this case, regulation is required (Bel and Fageda, 2013; Forsyth, 2003b; Gillen, 2011). The aim of the regulation is to give the airport incentives to maximise profits, but to constrain their use of market power in a way that does not weaken their motivation to minimise costs. As Amos (2004) indicated, economic regulations that govern transport are important in situations where the infrastructure or service involved is a natural monopoly, and/or where it confers significant market power. These conditions do not always apply, particularly in the supply of transport services. In cases “where there is reasonable competition in supply, market forces will normally be preferred to economic regulation” (Amos, 2004: 7).

2.2.1 Impact of Ownership

Studies that assess the effects of ownership, by comparing the efficiency of public and private airports, again do not reach clear conclusions. Oum et al. (2003), Lin and Hong (2006), and Vasigh and Gorjidooz (2006) measured the effects of ownership on a worldwide set of airports, and revealed no significant relationship for financial and
operational efficiency. Oum et al. (2003) argued that the extent of managerial autonomy dominates the effect of ownership. Furthermore, Vasigh and Haririan (2003) made a case that privatised airports intend to maximise their revenues, whereas public airports aim to optimise traffic. Barros and Marques (2008) found that private airports operate more cost-efficiently than their partially private counterparts. Oum et al. (2006) and Oum et al. (2008) were in favour of privatisation. In contrast to previous studies, they separated airports owned by one public shareholder from airports with multi-level government involvement. Referring to Charkham (1996), they argued that different ownership and governance structures can affect the quality of managerial performance. Oum et al. (2006) reached the conclusion that public corporations are not more efficient than major private airports in all situations. However, airports that are mainly publicly owned, or have multiple government involvement, seem to operate significantly less efficiently than the other ownership forms. Oum et al. (2008) concluded that airports with major private shareholders are more efficient than public airports or airports with major public influence. Similar results by Vogel (2006), on a European set of airports, indicated that privatised airports operate more cost-efficiently, and receive higher returns on total assets and revenues. The same conclusion is also made by Fasone et al. (2014), who analysed a sample of Italian airports.

Most of the studies show, to differing extents, that privatisation provides several advantages to the airports and that private structures are more flexible and efficient than public ones. However, in terms of social welfare, for an uncongested private airport, its aeronautical charge was excessive compared to a public airport (Zhang and Zhang, 2003; Basso, 2008; Czerny, 2013). But Czerny further found that if such an airport is experiencing congestion, it is unclear whether the private airport charge is excessive. On the other hand, public airports enjoy the advantage of higher gearing and financial leverage. Curi et al. (2010) found that companies with public majority ownership
performed better than private ones because of the availability of higher amounts of public funds to expand their capacity. This is in line with the results obtained by Zhang and Zhang (2003) and Zhang and Czerny (2012) who found the profit-maximising airport is less incentivised to invest in capacity expansion than the welfare-maximising airport.

The empirical studies regarding privatisation's effect on prices are also inconclusive. Bel and Fageda (2010) and Bilotkach et al. (2012) focused on the effect of privatisation and regulation on airport charges in Europe. Based on a cross-sectional analysis of 100 large airports in EU, Bel and Fageda’s (2010) empirical results indicated that the airport charges of private and non-regulated airports are higher than public or regulated airports. On the other hand, Bilotkach et al. (2012) used a panel data on a sample of 61 airports in Europe over an 18-year period. They revealed that on average privatisation leads to lower aeronautical charges. Bilotkach et al. (ibid) explained that the contradictory result was caused by differences in the methodology used.

Therefore, Gillen and Mantin (2014) found that impact of privatisation varies from airport to airport and concession revenue is a key factor in the decision to privatise. Privatisation could result in a major loss of welfare if the potential for concession revenue is much smaller, compared to aeronautical revenue. However, a private airport will charge lower aeronautical fees to incentivise the airline to supply more flights and bring more passengers, if the potential for concession revenue is sufficiently large. In this case the economic welfare loss due to privatisation is minimised.

2.2.2 Impact of Regulation

Starkie (2001) was the first who questioned the necessity of price regulation for airports because he argued that airports are unlikely to abuse their market power whenever complementary commercial activities exist. Starkie (2001) concluded that, for non-
congested private airports, increased airport aeronautical charges would reduce the demand for flights and commercial services, which in turn would diminish the revenues. Thus, airports may not see benefits in raising aeronautical charges, making airport regulation unnecessary. In contrast, Zhang and Zhang (2003) as well as Oum et al. (2004) and Basso (2008) pointed out that although there is a negative effect from concessions on the aeronautical charge at an unregulated profit-maximising airport, it would not set them at a socially optimal level so that a price regulation may be necessary. Hence, it is not completely clear that airports will actually abuse their market power, in which case the regulation of charges would be inappropriate (Brueckner and Van Dender, 2008).

Forsyth (2003b, 2008) contended that a light-handed approach could lead to distorted investment incentive and thereby to the inefficiencies of cost-plus regulation. The Australian Productivity Commission (2006) also found the light-handed regime has made it easier for the airport to undertake the new investment and increase the charge to airlines for that investment (Littlechild, 2012; Arblaster, 2014). Yang and Fu (2015) suggested that light-handed regulation is a promising regime although its relative performance to existing regulations depends on many market factors, e.g. demand, competition.

In the cases where airports are price regulated, choice of single-till or dual-till regulation is of major concern to airlines (Gillen, 2011; Yang and Zhang, 2011). In terms of single-till or dual-till regulation, there is also a debate on which is preferred by airports. The scholars have applied analytical and empirical methods to investigate the impact of these two forms of price regulation on the airport from different perspectives. When regulated, the charges are a function of the type of policy: aeronautical charges (landing fees) depend on the level of complementarity between the two main types of activities – airside and commercial. Dual-till pricing means that unregulated airports may charge higher prices compared to public airports, even though both would obtain the same concession profits.
(Zhang and Zhang, 2003). Single till regulation will result in lower landing fees, but this may lead to congestion if the airport has capacity limitations and aviation activities increase above a critical threshold. As Kratzsch and Sieg (2011) showed, with positive non-aeronautical revenues, a single-till regulation will always result in lower landing fees and in a higher social welfare than laissez-faire for an uncongested private airport. Additionally, if non-aeronautical revenues lie above a critical threshold, a dual-till regulation is unnecessary. For congested airports, a dual-till regulation would have positive effect on relieving congestion and on promoting investments, because of the higher aeronautical charges.

Oum et al. (2004) provide empirical evidence that dual-till price cap regulation dominates single-till regulation in terms of economic efficiency. Lu and Pagliari (2004) analysed the potential impacts on social welfare based on the model of Starkie (1998) and Zhang and Zhang (1997) and found single-till yields more welfare at non-congested airports, but dual-till is superior for congested airports. Therefore, Czerny (2006) and Yang and Zhang (2012b) concluded that the dual-till approach should be applied when aeronautical capacity is fully utilised or over-utilised at congested airports, since low aeronautical charges under single-till regulation would make congestion worse, while single-till would be desirable when excess capacity exists.

The debate on price regulation is also reflected in empirical studies. Based on empirical analysis in EU, Bel and Fageda (2010) found that the regulation mechanism does not seem to have any relevance to airport pricing, while Bilotkach et al. (2012) indicated that no obvious relationship appeared between price-cap regulation and aeronautical charges. However, Adler and Liebert (2014) recently reported that airports operating under a dual till are more productive. Adler et al. (2015) provided an assessment based on a data envelopment analysis (DEA) estimation of the relative efficiency of 58 airports in Europe to analyse how regulation affects performance. They found incentive
regulation has a positive effect on productive efficiency and pure price caps appear to have the strongest impact on short-term productive efficiency.

According to Vickers and Yarrow (1991), privatisation cannot be seen as a universal solution and should not be separated from the economics of competition and regulation, which are all determinants of corporate incentives. As previous literature looked at the separate impact of ownership and regulation on airport performance, it is difficult to draw conclusions on the combined effect. Therefore, recently more researchers have been interested in the joint impacts of ownership and regulation under different conditions like competition. Bel and Fageda (2013) investigated the dynamic relationship between privatisation and regulation in a context with varying degrees of competition, based on the data of 100 European airports. They found that the degree of regulation depends on the market power of a privatised airport. In this way, the regulatory authorities may opt for less prescriptive regulation to be applied to the privatised airports subject to significant levels of competition. This finding is supported by Adler and Liebert (2014) who combined all factors of influence in an Australian–European semi-parametric two-stage research. Adler and Liebert (2014) indicated that regulation can be replaced by effective competition in order to ensure cost-efficiency. Furthermore, public and major or fully private airports appear to operate equally cost-efficiently. Hence, no clear answer exists with respect to the ownership form in competitive situations. This supports the inconclusive results of the impact of ownership in different airport operations.

Assaf and Gillen (2012) examined the joint impact of governance and regulation on airport efficiency. Their empirical investigation used a semi-parametric Bayesian distance stochastic frontier model, as well as a DEA model based on a panel of airports in several countries. They found that the form of economic regulation is relatively more important than the type of governance in affecting efficiency. The main result of their research is illustrated in Figure 2.1.
Their work showed that the level of price regulation drives efficiency, although the starting point still matters. Therefore, in jurisdictions where there is a shift to full or partial privatisation, the efficiency gains that would arise from such a change in governance can be undone by imposing a heavy handed form of regulation such as single till.

Zhang and Czerny (2012) provided an interpretive review of recent research regarding the impact of ownership and regulation on airport pricing. They concluded that, from the social perspective, a private and monopolistic airport may charge excessive prices. In terms of capacity, if the passenger demand is fixed, the private airport would overinvest in capacity when carriers have market power. Regarding the regulation, there is evidence that price-cap regulation may be preferred to the rate-of-return regulation. However, when concession revenues are included, they could reduce the private airport’s charge rate. If there is plenty of capacity, a single-till formula should be used to better approximate marginal cost pricing in the aeronautical charge. By contrast, if capacity is limited, the dual-till formula may be appropriate because of the potential congestion.

Yan and Winston (2014) applied a three-stage game model into San Francisco Bay area airports to explore the potential effects of private airport competition on runway prices and the social welfare implications. They found that private airport competition could increase commercial travellers' welfare and airlines' profits, and enable the airports to be profitable under different conditions.
2.3 The Impact of the Market Structure of an Airport

The situation of the airport in the market dictates to a large extent the type of relationships it establishes with the airlines, and consequently its price structure and revenue (Starkie, 2008). Indeed, privatisation of airports, accompanying liberalization of the airline market and the emergence of low-cost carriers have significantly changed the market structure and the competitive environment faced by airports (Oum and Fu, 2008). Yuen and Zhang (2009) analysed 25 major Chinese airports between 1995 and 2006 to investigate the influence of competition and aviation policy reform. The results suggest that airports with more competition are more efficient than their counterparts and there is also strong evidence that publicly listed airports are significantly more efficient than non-listed airports. Allroggen and Malina (2010) developed a game model of hub competition including the downstream airline competition and found that airline competition limits the market power of the airport and there is incentive for the hub airport and its respective network carriers to optimise the profit of the overall network jointly. Therefore, the strict economic regulation of the business relationship between hub airport and its network carriers is unnecessary. Their results are consistent with the conclusions drawn by Zhang and Zhang (2010).

Indeed, the impact of the market situation of airports and airlines on airports’ pricing decisions has been top of recent policy debates.

Fu et al. (2006) looked into the differential competitive effects of changing airport user charges on airlines. They found that an identical increase in airport charge will affect the airlines to different degrees, and that airlines cannot fully pass on such an external price increase to consumers. As a result, the increase in airport user charges would harm competition in the downstream airline markets.
Using regression equations based on the data covering 55 large US airports from 1998 to 2002, Van Dender (2007) assessed the impact of the market structure on airport aeronautical and non-aeronautical charges. The results indicated that aeronautical fees are lower at airports with significant local competition and that they increase with airline concentration, Southwest being the biggest airline at those airports. The same econometric models enabled Van Dender to draw conclusions on the non-aeronautical or concession revenues/passenger: these fees are lower at hubs, most probably because of the high share of connecting passengers not requiring parking or renting a car. However, the finding that non-aeronautical revenue per passenger declined with the increased concentration of airlines implied that the composition of traffic has an impact on airport revenue. Another interesting result in this research was that concession revenues are higher in clusters of airports, which could be explained by these airports having to raise more revenue from non-aeronautical activities to compensate for the loss of aeronautical revenue led by competition between the airports. However, since US airports operate as public utilities by charging simple cost-based aeronautical fees, Van Dender’s results may not apply in other cases.

The European airports provide more context. Bel and Fageda’s (2010) study of 100 large European airports in 2007 led to a similar conclusion: the airport competition with other modes and airport competition from nearby airports located within 100 km (managed by a different operator) had a negative impact on the aeronautical price. Besides this, airlines with a larger market share of local traffic at a particular airport have greater negotiating power with the airport; the greater this negotiating power, the lower the prices they are charged. In comparison to network airlines, low-cost airlines seem to have greater negotiating power, since network traffic is more important for network airlines and the network of those airlines is dependent on the airport position.
The competitive market forces are expected to decrease aeronautical charges. As shown by the scholarly work above, there are at least two such forces affecting airport pricing: competition from a proximate airport as a close substitute and bargaining power from airlines. Haskel et al. (2013) is perhaps the first study to investigate the joint impact based on a formal theoretical setup. From their airport-airline model, Haskel et al. (2013) found that airport competition reduces landing fees and this effect is stronger when route substitutability is higher. Additionally, higher airline countervailing power always reduces aeronautical charges. These findings are supported by more recent empirical study by Bottasso et al. (2015), using a panel of the 24 largest UK airports.

However, the study by Bilotkach et al. (2012), employing data of 61 European airports during 1990-2007, showed the opposite effect, that the presence of nearby airports located within 90 km around the airport does not affect aeronautical charges. This is also confirmed by the more recent study by Choo (2014) in US, which showed that both airport competition (the number of airports with more 100,000 passengers within an airport’s 100 km catchment area that are managed by a different operator) and airline bargaining power (measured by the market share of the dominant airline) do not significantly affect aeronautical charges. Choo’s study (2014) used data of 59 major US airports during 2002-2012.

The partly conflicting results of the previous empirical studies may be due to difference in samples, e.g. different regions and time period. However, the role of competitive markets has been acknowledged, and the airport competition with other modes (e.g. HSR) is a recent focus of many studies, especially in Europe and Asia. They are discussed next.
2.3.1 Impact of Competition with High Speed Rail (HSR) on Airport

Janic (1993) appears to be among the first to develop a model of competition between the two travel modes, concluding that high-speed rail can compete with air transport over a relatively large range of distances (from 400 to over 2,000 km). More recent studies supported the finding that HSR has demonstrated its advantage in the short-haul or medium-haul route <800 -1,000km (Albalate et al., 2015; Fu et al., 2012; Givoni 2006; Givoni and Dobruszkes, 2013; Martin and Nombela, 2007; Roman et al., 2007; Steer Davies Gleave, 2006).

Generally, the introduction of HSR had a negative impact on the market share of air transport. A number of empirical studies showed how air traffic suffered the most marked impact (Campos and De Rus, 2009; Gonzalez-Savignat, 2004; Givoni, 2006; Givoni and Dobruszkes, 2013; Martin and Nombela, 2007; Roman et al., 2007), although De Rus and Nombela (2007) reached the conclusion that ‘high-speed rail investment is difficult to justify when the expected first year demand is below 8 – 10 million passengers for a line of 500 km’ which they demonstrate is unlikely in the majority of transport corridors in Europe (pp:18).

The introduction of HSR influences travel behaviour in several ways: a) additional alternatives for mode choice (switch from air, car and conventional rail); b) airport choice (airport accessibility increased by HSR connection); c) airline choice (airlines have integrated HSR links into their networks); d) induced demand into the O-D market (Terpstra and Lijesen, 2015).

All the scholarly work regarding the HSR is quite conclusive in that HSR is extremely competitive with other modes, particularly for short-haul, intercity markets (Haas, 2014; Behrens and Pels, 2012). In this study, I focus on the impact on airport of competition between air transport and HSR.
Influencing factors of modal shift

Traditionally, total journey time (including access time, waiting time and travel time), frequency and fares have been the common variables used for predicting the modal split among modes.

Givoni and Dobruszkes (2013) assembled data from a variety of existing studies and offered conclusions regarding the factors influencing the model shift: travelling time (including the access time to and from the airport) is the prime determinant of both demand for HSR and modal shift to HSR. Compared with other modes, the HSR market share falls as travel time increases. It is reasonable to assume that travel time of HSR is the main factor explaining the demand for HSR and the level of mode substitution. Steer Davies Gleave (2006) found that travel time explains 84% of the difference in market share of rail (including HSR) vs. air on eight different European routes. Their report concluded that travel time by HSR (not distance) was the most significant factor impacting market share while service frequency and fare levels will not affect this market. Givoni (2006) concluded that shorter travel times and an increased level of service (a higher frequency and also improved travelling conditions) increased the HSR modal share. His argument relies on before-and-after comparisons of the French Paris-Lyon TVG line during 1981-1984 and the Spanish Madrid-Seville line from 1991-1994. It is also supported by the survey on the 222-km Rome–Naples route by Cascetta et al. (2011) and the study on the inter- and intra-modal competition in the London-Paris passenger market by Behrens and Pels (2012). They latterly found travel time and frequency as the main determinants of travel behaviour. Compared to leisure passengers, business passengers are more sensitive to lower total travel times, and higher weekly frequencies, but less sensitive to fare. Furthermore, for both groups, the sensitivities to total travel time are considerably lower for low-cost alternatives. However, the sensitivities towards total travel time increased for all airlines after HSR entry into the market. In addition, the
results showed that the direct elasticity of market share with respect to frequency, for those airlines that subsequently left the market, is above 1. This indicated that these airlines were not able to maximise profits. The only frequency elasticity of market share below 1 was for LCC.

Several studies qualified their results according to the fares being charged. For example, Steer Davies Gleave (2006) showed that competition between HSR and air transport is less straightforward where LCCs are present. This is due notably to the inflexible price of HSR. As Friebel and Niffka (2009) showed for the German case, HSR pricing is not straightforward and there are more barriers for change or reduction.

Although it is reasonable to expect fares to influence mode choice, and some evidence for this was found, the few studies that report price elasticity suggest that it might not be as important in determining mode choice. For example, Campos and Gagnepain (2009) computed cross-price demand elasticities on the Paris–Amsterdam route in 2005. They found that HSR would not attract air passengers from traditional airlines or LCCs with lower fares. In contrast, HSR would gain air passengers if traditional airlines increase their fares.

**Determinant factors of regional travel choice in China**

Zhang et al. (2012) considered four factors influencing passengers’ choice for regional travel: travel time, cost, comfort and safety. Not surprisingly, time and cost appear as dominant attributes for China as well.

Fu et al. (2012) suggested that the network connectivity will make HSR service in China even more competitive, as the development of the Chinese aviation market has been unbalanced, with growth mainly driven by domestic routes linking a few major airports. Furthermore, major domestic airports have suffered capacity shortages. Together with the air space congestion, airlines find it difficult to enhance their on-time
performance, or to compete with HSR by increasing flight frequency. Based on these attributes, the conclusion is that the airlines may have to transform from their current point-to-point networks to effective hub-and-spoke networks and expand their international routes. Finally, Fu et al. (2012) suggested that Chinese airlines would survive after the entry of HSR into the market by exploiting their competitiveness in terms of cost efficiency, service quality and contribution to long-term regional and global economic growth.

Yang and Zhang (2012a) used a competition model, based on total journey time, to examine the impact of HSR on air transport. In their model, different objective functions were set for the airlines and for the HSR operators. While the airlines are profit maximisers, the objective for HSR operators is likely to be a weighted sum of social welfare and profit, especially in the case of China, where the HSR is operated by a state-owned company – China Rail High-speed (CRH). Based on a homogeneous-passenger model, it was found that both the airfare and HSR price decrease as the weight of welfare in the HSR objective function increases. However, airfares diminish with a rise in the airport access time, while rail fare increases. The study also found that, overall, airfares decrease with the rail speed when the marginal cost of HSR is not too high (because increased HSR speeds put pressure on air transport to become more competitive). In contrast, two elements affect the rail prices when rail speed increases: marginal cost of HSR and its effect on welfare. When the basic model extended to the case of heterogeneous passengers, the two different cases (business and leisure travelers) displayed distinct travel benefits and values of time. The results varied depending on whether airlines charge different rates to the business passengers and leisure passengers. Yang and Zhang (2012a) showed that, compared to uniform pricing, fewer business passengers travelled by air transport when “price discrimination” was applied, whilst more leisure passengers travelled by air transport with “price discrimination”. This
resulted in greater consumer benefits for HSR. Finally, the airline profits were higher under price discrimination, while the profits of HSR stayed unchanged (as HSR did not engage in price discrimination).

Using a completely different approach, Zhang et al. (2012) described the changes in passenger numbers in response to the dynamic pricing of HSR and air transport in a game theory model drawing, on Stackelberg’s competition model. They found that HSR tends to balance ticket prices around ¥39 and the airlines at ¥56. However, their conclusions are limited in practice, given the modelling assumptions (same cost regardless of the number of passengers, running time for 100km.) and anchoring of air prices on HSR prices.

**Market share**

Gonzalez-Savignat (2004) developed a stated preference experimental design to analyse the potential attraction of a HSR link from Madrid to Barcelona. He predicted a high substitutability between air services and the rail link if upgraded, arguing that HSR is expected to achieve 40% market share in the business sector and almost 60% in the leisure sector. Park and Ha (2006) found the share of air traffic fell from 40% to 13% during 1991-1994 on the Route Madrid - Seville. More recently, Albalate et al. (2015) showed that, in 2009, HSR had 85% of the market share on the Madrid - Seville route and 70% on the Madrid - Malaga route, compared with only around 50% on the Madrid - Barcelona route.

Givoni (2006) indicated that the French a Grande Vitesse (TGV) line resulted in a 24% loss of market share for air transport in France, with a 27% loss in Spain. Both Martin and Nombela (2007) and Roman et al. (2007) reached the conclusion that after upgrading the infrastructure, a high-speed rail operator will attract approximately 25% of
the passenger market share, a very similar conclusion to that of the Nanjing case study (on average), as shown later in Chapter 6.

In De Rus and Nash’s study in 2007, they implied that the European air services faced severe cutbacks immediately after HSR entered the market and for the following two to five years. By 1997, the airlines’ share of domestic travel had decreased by nearly half, from 30% to 16%. Similarly, in Taiwan, the market share of air transport on the route Taipei – Kaohsiung fell from 24% to 13% following the entry of HSR (Cheng, 2010).

Campos and De Rus (2009) analysed information from 166 HSR projects globally and provided a new overview of the growth of HSR demand in a variety of countries and regions. With respect to the modal share in these systems, they indicated that HSR accounts for 40% of the total passenger market over medium distances in Europe and Korea, where total domestic air travel dropped significantly just two years after HSR introduction (through 2006). However, they did not provide more detailed information about the modal shift.

Givoni and Dobruszkes (2013) reviewed data from a variety of existing studies and offered conclusions that HSR can capture more than 50% of the market when travel time by HSR is within about 3.5 hours, and the share generally decreases with the increase in travel time. Furthermore, the induced demand share of HSR ranges from 6% to as high as 37% up to four years from the launch of HSR services, and around 75-90% of HSR demand is shifted from other modes of transport. From their analysis, among 22 routes with distance between 160km and 621km, covering Europe and Asia, the rate of air transport decreased from 100% to 20% after HSR entry and the rate decreased with the route distance.

Airline and airport responses to the HSR introduction on the market
The impact of HSR entry is not only on the market share, but also on airfare reduction. Steer Davies Gleave (2006) showed how airlines reduced their airfares, to the extent that they could fall below corresponding HSR fares, to competing HSR in European markets. Their research is also supported by Dobruszkes (2011) and Yang and Zhang (2012).

Additionally, the introduction of HSR services may result in the cancellation of air services on particular routes. De Rus and Nash (2007) presented a forecasting model to illustrate how the airlines and HSR will adjust their costs and prices in response to direct competition and indicated that airlines do not necessarily exit an inefficient market, as sometimes they need existing routes to feed traffic to more profitable routes.

Dobruszkes (2011) examined empirically five city-pairs in Europe to measure the impact of HSR on airline supply. He found that, for a given city-pair, the airline would decrease the number of flights, depending on its own strategies and the length of the HSR journey. Some carriers reduce their supply in terms of the number of seats, by using smaller aircrafts, but increase the number of flights in order to compete more effectively with the HSR.

Although it is clear that the introduction of HSR has had a significant impact on the airlines, Steer Davies Gleave (2006) acknowledged that competition between HSR and air transport is less straightforward when air services are operated by low-cost carriers (LCC), which is supported by Adler et al. (2010). Clewlow et al. (2012, 2014) also indicated that the presence of LCC at European airports has a significant positive impact on intra-EU air travel demand. The literature regarding LCC is presented in Section 2.3.2.

**Competition and cooperation between air and HSR in China**

In recent years, several studies were dedicated to the Chinese aviation market, however, few of them focused on the impact of the HSR, mainly because of the short-term history of HSR in China commencing in 2009.
In a logit model, Zhang et al. (2012) compared the air transport and HSR and concluded that the substitution effect of high-speed rail reaches its peak and the competition becomes fierce for distances within the 600-1,400km range. Furthermore, the most competitive transport distance increased by 124.7 km for air travel (and decreased for HSR), when HSR fares declined by ¥ 0.1/passenger km. Similarly, CAAC (2013) warned that 50% of flights on routes shorter than 500 km could become unprofitable as the result of the competition from HSR, and around 20% of flights of between 800 and 1,000 km could also run at a loss. They predicted HSR could capture between 1.3% and 5.3% of domestic airline passengers per year by 2014. The distance range effect was also confirmed by Fu et al. (2012), who found that routes below 1,000km experience the most effect of competition from HSR in China. Fu et al. (2012) further investigated the effects of the HSR services on Chinese airlines by comparing their unit cost. From the analysis of the Guangzhou-Changsha-Wuhan route, they concluded that Chinese airlines are unable to compete with HSR on routes shorter than 1,200km, even when considering cost-based pricing (however, their research has not included LCC).

Bullock et al. (2012) and Givoni and Dobruszkes (2013) analysed traffic data from several HSR routes and found a substantially induced demand of HSR passengers on the Wuhan-Guangzhou (968km) and Beijing-Tianjin (131km) routes. Including newly generated demand and mode transfer from car travel, the two HSR routes increased their patronage by 45% and 80% respectively. Additionally, for Wuhan-Guangzhou, 5% of the demand for HSR was shifted from air transport.

Besides competition between HSR and air transport, recent research has started to focus on cooperation between the two modes. Cooperation is relatively new and its market outcomes largely unknown. The European Union provides examples of cooperation and promotes it by putting forward two arguments: relief of congestion at major airports and positive environmental benefits (European Commision, 2001).
Lufthansa and Deutchsche Bahn, Air France and SNCF/Thalys, SBB and Swiss and FinnAir are already providing integrated air-rail services for passengers. However, little quantitative evidence is available for assessing their impacts. Using a hypothetical network (with three cities where intercity transport services are offered on two links) and simulation, Jiang and Zhang (2014) analysed the effect of cooperation between a hub-and-spoke airline and HSR at a capacity-constrained hub airport. They found that modal substitutability and capacity limitations have impacts on the welfare. For low substitutability, cooperation increases welfare. For high substitutability, capacity is key: cooperation is beneficial in constrained hubs, but it reduces the welfare in un-constrained hubs. Moreover, cooperation reduces traffic in markets where prior modal competition exists, but it may increase traffic on other markets of the network.

2.3.2 Impact of LCC on the Airport

The low cost carrier model first emerged with Southwest Airlines in the USA in 1971 and has been copied and adapted by numerous airlines in almost all regions of the world (Doganis, 2006). There is a growing amount of literature related to the changing nature of the airport industry and the new commercial challenges that have emerged. This is because whilst the LCC sector has been developing, the airport industry has being going through a metamorphosis (Graham, 2008). In terms of geographical coverage, by far the most popular region researched was Europe (Bilotkach et al., 2015; Bubalo and Gaggero, 2015; Clewlow et al., 2014; Francis et al., 2003, 2004, 2006; Graham and Dennis, 2010). A number of these articles focused on particular countries such as the UK, Ireland, Italy and Spain (Castillo-Manzano, 2010; Donzelli, 2010; Lei and Papatheodorou, 2010). A further few articles looked at North America, for example US (Cho et al., 2015; Choo and Oum, 2013; Dresner et al., 1996; Dresner, 2006; Elwakil and Dresner, 2013; Fu et al., 2011a; Volkova, 2010; Windle and Dresner, 1999). This reflected the earlier development
of the LCC model in these regions with a number of papers adopting a broader coverage or a more general non-specific geographical emphasis. By contrast, the majority of the articles concerning the Asia and Pacific region were published since 2008 (Chung and Whang, 2011; Fu et al., 2015; Lu and Mao, 2015; Pearson and Merkert, 2014; Zhang et al., 2008; Zhang and Lu, 2013).

Dresner et al. (1996) indicated that the presence of LCCs contributed to lower fares and higher traffic volume on the competitive routes (e.g. Southwest entering the Baltimore-Washington International (BWI)-Cleveland route), using the data of top 200 US domestic routes. Numerous previous studies showed that the presence of LCCs may have a positive effect on the airport traffic (Cho et al., 2015; Dresner et al., 1996; Fu et al., 2011a, 2015; Morrison, 2001; Oliveira, 2008; Windle and Dresner, 1999).

There is more limited discussion relating to whether LCC growth at airports can be translated into an actual benefit of increased profits (Graham, 2013). Francis et al. (2004) found that airports, particularly secondary airports, are motivated to negotiate lower airport charges and provide other financial incentives to attract the LCCs. This is because LCCs can threaten to leave stranded airport assets by flying elsewhere and switching to substitute airports. Moreover, Gillen and Lall (2004) showed how the negotiating power of the single dominant LCC may increase. Indeed, both Barbot (2006) and Malighetti et al. (2010) found the airfare of Ryanair lower when its flights departed from or arrived at airports where Ryanair dominated. This suggests that domination enables the airline to agree better charges deals, although Barbot (ibid.) did add that it may also be due to economies of scale or ‘airport density’ leading to lower unit costs for the airline. However, Choo (2014) found that when the airport was not dominated by LCCs, it enabled it to charge cheaper aeronautical fees for LCCs (e.g. Southwest).
The airport operator will offer a variety of deals to encourage LCC services, which differ substantially in nature: for example, the airport may apply a discount on all airport charges, or a more risk-sharing all-inclusive passenger charge replacing the weight-related landing charge and separated passenger charge (Graham and Dennis, 2007). In other cases, where the differentiation of landing and passenger charges is prohibited by government, discounts on handling charges may be given instead. Moreover other incentives or marketing support could be provided by the airport in order to help LCCs cover the costs of marketing the new services and other start-up expenses (Graham, 2013; Starkie, 2012). Barbot (2006) and Fu et al. (2006) confirmed that such pricing incentives benefitted consumers and negatively affected the full service airlines (FSAs).

Low airport fees and other incentives are likely to be applied to attract LCCs to an airport to fill up spare capacity, with the focus being placed on the marginal revenues and costs rather than full cost, revenue and capacity considerations and the long-term sustainability of such a start-up strategy (Francis et al., 2003). Many airport operators seek to obtain higher non-aeronautical revenues from the increased number of LCC passengers and their spending to compensate the reduction in aeronautical revenues. Graham and Dennis (2007) argued that LCC passengers are not necessarily budget spenders on commercial facilities, e.g. more dwell time or a longer operational day to shop, which is supported by Njoya and Niemeier (2011) and Castillo-Manzano and López-Valpuesta (2014). Saraswati and Hanaoka (2014) also found that in Soekarno-Hatta Jakarta airport, the food and beverage (F&B) services were the most popular outlets for LCC passengers. Therefore, LCC passengers may have a strong demand for F&B facilities because of limited offerings on board. Also, as Lei and Papatheodorou (2010) concluded, when the number of visitors (meeters and greeters) increased, because of a higher proportion of leisure passengers generally on LCC services, these facilities have a
greater use. In addition, car parking and car hire revenues may also increase because of the use of more remote secondary airports.

Francis et al. (2003) showed that, at a secondary European airport, the revenue per passenger in shops was €8 for LCCs compared with an average for all passengers of €5.5. Likewise, in the case of Canadian airports, McDonald and Gillen (2003) (cited in Lei and Papatheodorou, 2010) found that an additional LCC (WestJet) passenger brought C$6.20 of non-aeronautical revenue compared to C$1.22 for a non-LCC passenger. This was supported by Francis et al. (2004). They concluded that % of non-aeronautical revenues at Luton airport rose from 45% in 1995 to 59% in 2001 as the share of LCCs increased. Meanwhile, Gillen and Lall (2004) observed that non-airline revenue per passenger increased from $9.70 to $10.55 at Albany airport in US after Southwest started services. More recently, Volkova (2010) found, based on the study of US airports during 2004-2008, LCC passengers contribute more to non-aeronautical revenue (F&B, parking and car rental) than FSA passengers, except for retail activities. Despite, this previous evidence from empirical studies, the contribution of LCC to non-aeronautical revenues is patchy and inconsistent. By contrast, Castillo-Manzano (2010) found that, at a Spanish regional airport, the shopping behaviour of LCC passengers showed very similar to those using FSAs, but actually spent 7% less. This was also noted by another study of UK airports undertaken by Lei and Papatheodorou (2010). They found that the non-aeronautical spending of LCC passengers was on average £2.87, compared with £5.59 for FSA passengers. However, given their uptake, in terms of total commercial revenues, Lei and Papatheodorou (2010) and Castillo-Manzano (2010) acknowledged the contribution of LCC to the UK regional airports’ commercial revenue is increasingly significant.

There are also some uncertainties related to the LCCs’ impact on airport costs. Undoubtedly, extra LCC passengers and higher utilisation of airport facilities may have
minimal or marginal cost implications if this traffic can be accommodated within the design capacity of the airport (Francis et al., 2004; De Neufville, 2008). Airport costs may also be reduced by having better utilisation of resources if the LCCs smooth the seasonal pattern of traffic, with a more even spread of demand (Chung and Whang, 2011; Donzelli, 2010; Graham and Dennis, 2010).

Therefore, the conclusions are ambiguous and mixed on the issues related to airport financial performance and LCC operations. Graham and Dennis (2007) argued in their study of UK and Irish airports that there was no obvious relationship between airport profitability and LCC operations, although the airports served by LCCs tended to have lower unit revenues because of lower airport charges, and also lower unit costs. Papatheodorou and Lei (2006) assessed the financial performance of two UK regional airports and found that both the FSAs and charter carriers had significant, if not higher, contribution to both aeronautical and non-aeronautical revenues compared to the LCCs. However, Lei and Papatheodorou (2010) confirmed the contribution of LCCs to UK regional airports’ commercial revenue is increasingly significant. Additionally, Volkova (2010) concluded that US airports can get higher non-aeronautical revenue from LCC passengers than from passengers of traditional airlines, which compensates for the reduction in aeronautical revenue. Nevertheless these findings are based on individual cases from different regions, therefore explanations for the differences in LCC impact on airports among countries are needed.

2.4 Impact of Airport-Airline Relationships on Airport Revenue

2.4.1 Agreements between an Airport and Airlines

When an airport faces competition from another airport, either adjacent or another hub, it is in its interest to form an alliance with airlines, normally with the dominant carrier
(Barbot, 2009; Fu et al. 2011b). Regardless of the type of contract (price negotiation, controlling airport facilities or revenue sharing), consumers are better off because of the enhanced offer of services (e.g., fast-improving facilities, increased number of flights, greater diversity of concessions).

The benefits for both airports and airlines from entering into relationships or agreements have been well documented (Barbot, 2009, 2011; Barbot et al., 2013; Oum and Fu, 2008, 2010; Fu et al., 2011b; Yang et al., 2015). Starkie (2008) presented a comparative analysis of three cases (Europe, Australia and US) highlighting the main types of agreements between airports and airlines. Barbot (2009) applied a two or three-stage game framework to explore the effects of vertical contracts on airport pricing. Game models were further employed by D’Alfonso and Nastasi (2010) and Fu and Zhang (2010) to assess aeronautical pricing and revenue sharing. According to both studies, revenue sharing allows the airport and airlines to internalise a positive demand externality between aeronautical services and non-aeronautical services. Fu et al. (2011b) reviewed and summarised the forms and effects of vertical relationships and concluded that the positive externality of the airport’s aeronautical activities on the commercial services can provide incentives for both airport and airlines to strike exclusive deals. Through collusion or different agreements, airports can obtain financial support and secure business volume, important for their daily operation, as well as for long-term expansion. On the other hand, airlines can secure key airport facilities on favourable terms, essential for making long-term commitments at the airport (Fu et al., 2011b). Saraswati and Hanaoka (2014) supported and complemented earlier findings. They showed that commercial revenue sharing increases an airline’s marginal revenue and an airport prefers to share revenue with the dominant airline in order to gain optimal benefit. More recently, Yang et al. (2015) suggested, in their empirical study of major airports around the world,
that airport-airline vertical arrangements are more likely to be formed when airlines have greater market power or higher costs and airport charges are higher.

However, revenue sharing may cause a negative effect on airline competition (Fu et al., 2011b; Saraswati and Hanaoka, 2014; Zhang et al., 2010). Price negotiation (or vertical merger) and the operation of terminals or other airport facilities by airlines are anti-competitive. Different levels of complementarity, substitution or independence between services may cause a fierce rivalry between airlines with similar features (Barbot, 2011; D’Alfonso and Nastasi, 2012). To avoid such an outcome, depending on the type of relation, different regulation policies may be recommended with the aim of avoiding market foreclosure and price squeezes (Barbot, 2011; D’Alfonso and Nastasi, 2012; Fu et al., 2011b). However, regulation should not be seen as a “sweeping solution” as it has been shown to “lead to inefficiencies such as underinvestment and loss of service quality” (Gillen, 2011: 11).

2.4.2 Airport –LCC Relationship

Traditionally, the vertical arrangements have been restricted by government (Yang et al., 2015). Such restrictions, together with the historical public utility status of airports, has excluded most airports from anti-trust investigations until the recent airport privatisation. As discussed in Section 2.3.2, there is considerable agreement that the emergence of the LCCs have had a major impact on the airport-airline relationship (Francis et al., 2003, 2004; Humphreys et al., 2006; Starkie, 2012). Airports are willing to attract the LCCs to grow passenger numbers and fill underused capacity, or to prevent the LCCs from moving on to another airport by signing different short-term agreements with them. Njoya and Niemeier (2011), using the example of Bremen airport where Ryanair had invested in the terminal, suggested that airports may get airlines actively involved in airport activities and investment by vertical integration, in order to mitigate some of the risks and create
greater stability. In the long-term, however, there needs to be a more fundamental assessment of the sustainability of the relationship between the LCCs and the airport (Graham, 2013).

A possible future strategy for airports handling both FSAs and LCCs with different demands would be for the airport to provide different services. Gillen and Morrison (2003) discussed how the unbundling of airport services is important in the LCC-airport relationship, arguing that just as LCCs and FSAs have unbundled services to compete with each other, the same will be become true for airport competition. Their research suggested that there might be more sophisticated contracts of airports catering for either LCCs or FSAs. They also indicated that managing the trade-off between aeronautical and non-aeronautical revenues is crucial when negotiating with LCCs and suggested that this is dependent on the level of integration between airports and airlines. Humphreys et al. (2006) pointed out that pressure from existing airlines to receive the same discounts in charges as LCCs can lead to unforeseen decrease in aeronautical revenue which could be not compensated by non-aeronautical revenue from LCC passengers. Therefore, the risk-sharing contracts between airports and airlines are suggested by some scholars to serve as a risk-mitigating tool for airlines to compensate for a downside loss of revenue and can be used as an incentive device to extract airport efforts (Barbot, 2011; D’Alfonso and Nastasi, 2012; Yang et al., 2015)

Therefore, the airport-airline relationship depends on the type of airport (including the size) and on the government. Medium or small airports are rarely subject to formal economic regulation, which may give them more flexibility when dealing with their LCC customers. The relationship may also be more complex if there is group management of different airports as implications for the whole group or airport system have to be considered (Barrett, 2004; Fageda et al., 2011).
2.5 Integrated Analysis of Airport Revenue Factors

The literature, so far, has focused on either governance, market power, or airport-airline relationships, but scholarly work on the combination of all the factors affecting the airport revenue is lacking. Recently, this has come to the attention of more researchers, who have started to focus on the multi-factors influencing airport aeronautical charges and airport efficiency.

Bel and Fageda (2010) examined factors influencing airport aeronautical pricing using a sample of 100 European airports with the highest traffic volumes and gave comprehensive consideration to the influence on pricing of airport ownership and regulation, the potential competition from other modes or other airports and the type of airlines that operate out of them. They found that competition from other transport modes and nearby airports imposes some discipline on the pricing behaviour of the airports. LCCs and airlines with a high market share seem to have a stronger countervailing or negotiating power. Additionally, private airports, not regulated, charge higher prices than public or regulated airports. However, they argued that the regulation mechanism does not seem to influence substantially the level of airport charges.

Assaf and Gillen (2012) examined the joint impact of governance and regulation on airport efficiency (Section 2.2) and concluded that fully-private airports with their price monitored represent the most efficient approach.

Ha et al. (2013) employed a regression analysis to estimate the impact of government structure, airport competition and airlines’ market structure on the airport efficiency. They used some dummy variables, such as ownership transition, HSR competition and customer power to classify the situation of an airport. It has been found that the technical efficiency of major Northeast Asian airports is negatively correlated
with decentralisation of airport ownership and operation, and that strong airport competition does lead to higher airport efficiency (ibid.).

More recently, Adler and Liebert (2014) studied the combined impact of ownership form, regulation and competition on airport performance and pricing in terms of cost efficiency on a sample of 48 European airports using data envelopment and regression models. They revealed that under non-competitive conditions, fully private airports are more cost efficient than the public airports and that regulation could help the airport operate more cost efficiently and charge airlines more reasonable fees. Under competition, although partly public and fully public airports operate equally efficiently, private airports would set higher aeronautical charges.

Still, all analytical and empirical approaches used in the previous studies limit, to some extent, the ability to apply models for optimising airport operation that encompass multiple influences. Therefore, a study that acknowledges the complexity of multiple and heterogeneous relationships and governance structures and their different contexts, and addresses them jointly, would be better equipped to capture the mechanisms through which airports pursue profitable operation.

2.6 Current Research Gap

Understanding the need for an integrated analysis of the complexity of relationships presented in the airport revenue system, this research views airports as two-sided platforms where airlines and passengers interact and, hence, it is the network of relationships that affects the efficient operation of the airports. By exploring the interactions governing the airport operation, it is possible to identify how the airport under different market power can optimise its revenue within the constraints and under specific ownership, airport-airline relationships and different regulatory schemes. The approach
employed in this study, System Dynamics, is a method of studying complex systems enabling us to cope with the complexity of the airport revenue system in order to find out main factors influencing the airport revenue. The methodology is introduced in the next Chapter.
CHAPTER 3  METHODOLOGY AND DATA COLLECTION

3.1 Methodology

Chapter 2 presented the literature on measuring and understanding the factors affecting airport’s revenue and efficiency, which has expanded considerably over the last few years. The methodologies employed to explore the structure of revenues and attempts to identify drivers for increasing airport’s profits or performance in various geographical contexts are multiple. Zhang and Zhang (1997 and 2003) applied optimisation models, Starkie (2002 and 2008) economic/econometric models and Basso (2008) numerical analysis; whereas Oum et al. (2004) and Gillen and Morrison (2003) relied on descriptive and qualitative analyses, and Fuerst et al. (2011) used macro level regression models. Most studies were based on panel data and only focused on one or two of the factors affecting the airport revenue. Since airport revenue systems are complex, the data involved may be massive, including some soft variables that are hard to describe with “crisp” values. Thus, any optimised model with supporting quantitative analysis or analytical solution is challenging in such a multi-variable interrelated system.

The methodological framework of Chapter 1, particularly Figure 1.1, suggests the development of an integrated, yet flexible, simulation model for the analysis of airport revenue that incorporates their complex interrelations. Chapter 1 showed that the research approach for achieving this goal has two key requirements:

(1) to cope with the complexity of the airport revenue system; and

(2) to analyse the airport revenue system using a holistic perspective.

Simulation is a suitable tool, meeting these two requirements for exploring the airport revenue system. However, there are several types of simulation. Figure 3.1 compares
The nature of the system (complex) and the dynamic processes to be modelled narrow down the repertoire of techniques to agent-based modelling (AB) and system dynamics (SD). Similarities and differences between the two approaches are indicated in Table 3.1.

Table 3.1  AB versus SD (according to Schieritz and Milling, 2003)

<table>
<thead>
<tr>
<th>Model element/characteristic</th>
<th>System Dynamics (SD)</th>
<th>Agent-Based Modelling (AB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic building block</td>
<td>Feedback loop</td>
<td>Agent</td>
</tr>
<tr>
<td>Units of analysis</td>
<td>Structure</td>
<td>Rules of interaction</td>
</tr>
<tr>
<td>Level of modelling</td>
<td>Macro</td>
<td>Micro</td>
</tr>
<tr>
<td>Perspective</td>
<td>Top-down</td>
<td>Bottom-up</td>
</tr>
<tr>
<td>Handling of time</td>
<td>Continuous</td>
<td>Discrete</td>
</tr>
<tr>
<td>Mathematical formulation</td>
<td>Integral equation</td>
<td>Logic or Rules</td>
</tr>
<tr>
<td>Origin of dynamics</td>
<td>Levels of interaction</td>
<td>Events</td>
</tr>
</tbody>
</table>

System Dynamics (SD) is the study of information – feedback characteristics of industrial activity to show how organisation structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of enterprise (Forrester, 1958,
It focuses on the structures that underlie complex systems and provides insight to the dynamic interactions among their elements, in order to understand how this behaviour is produced, and hence use this understanding to take effective actions (Forrester, 1994; Maani and Cavana, 2007; Morecroft, 2007; Richmond, 1993; Richardson and Andersen, 2010; Sterman, 2000). SD has a top-down perspective and applies Causal-Loop diagrams, Stock-and-Flow diagrams, and integral equations with time dimension to describe the system behaviour as a number of interacting feedback loops, balancing/reinforcing effects and delay structures.

On the other hand, Agent-Based Modelling (AB) operates with agents and environment, which interact with each other using specific local rules. This means that autonomous entities, endowed with certain behaviours and interactions may lead to complex spontaneous dynamics in the system (Bonabeau, 2001). Large changes could be driven by even subtle modifications, possibly imperceptible to agents having only local knowledge of the system’s relationships. AB is best suited to decentralised systems, where the emergent/self-organising patterns dictate the behaviour of the whole system (Bonabeau, 2001). Unlike SD simulation, AB has a bottom-up approach, which is not well suited to the structured airport environment. Given that the airport is not a decentralised system where the behaviour of the heterogeneous agents dictate the system’s outcomes, SD will be applied in this research considering two key points: (i) The aggregated behaviour is decided by the structure of the system (SD), not by the individual behaviours (AB); (ii) the modelling is from top-down (SD), not from the ground up (AB).

3.2 System Dynamics

System Dynamics is a method of studying complex systems. According to Richardson (1991: 144), SD “is a computer aided approach to policy analysis and design. It applies
to dynamic problems – problems that involve change over time – arising in complex social, managerial, economic or ecological systems – literally any dynamic systems characterized by interdependence, mutual interaction, information feedback and circular causality.”

Sterman (2000) completed this definition by highlighting the inter-disciplinary nature of the approach: ‘System Dynamics is fundamentally interdisciplinary. Because we are concerned with the behaviour of complex systems, system dynamics is grounded in the theory of nonlinear dynamics and feedback control developed in mathematics, physics, and engineering. Because we apply these tools to the behaviour of human, as well as physical and technical systems, system dynamics draws on cognitive and social psychology, economics, and other social sciences.’ (pp. 4-5).

Therefore, System Dynamics is a computer-aided approach to policy analysis and design. It is engaged in building quantitative and qualitative models of complex problems and then experimenting with and analysing the behaviour of these models over time. Such models are often applied to dynamic problems arising in complex social, managerial, economic, or ecological systems; reflecting the influence of circular causal relationships, dynamics and structural delays.

The SD approach involves the following (Martinez-Moyano and Richardson, 2013; Richardson, 1991; System Dynamics Society, http://www.systemdynamics.org):

- Defining problems dynamically, in terms of graphs over time;
- Striving for an endogenous, behavioural view of the significant dynamics of a system, a focus inward on the characteristics of a system that themselves generate or exacerbate the perceived problem;
- Thinking of all concepts in the real system as continuous quantities, interconnected in loops of information feedback and circular causality;
• Identifying independent stocks or accumulations (levels) in the system and their inflows and outflows (rates);

• Formulating a behavioural model capable of reproducing, by itself, the dynamic problem of concern. The model is usually a computer simulation model expressed in nonlinear equations, but is occasionally left unquantified as a diagram, capturing the stock-and-flow/causal feedback structure of the system;

• Deriving understandings and applicable policy insights from the resulting model and implementing changes resulting from model-based understandings and insights;

3.2.1 A Brief History of SD

System Dynamics was created by Professor Jay Forrester of the Massachusetts Institute of Technology (MIT), Cambridge, in late 50s. Disappointed with the prevailing approach and method of management science, which tended to view management issues as isolated problems at separated points in time, Forrester investigated the question of how one could apply the concepts and ideas of Control Theory and Control Engineering to management. In Industrial Dynamics (Forrester, 1961), Forrester's first book, he suggested the birth of System Dynamics modelling as a discipline in its own right, envisaging a considerable augmentation of the analytical strengths in the socioeconomic field.

From the late 1950s to the late 1960s, System Dynamics was applied almost exclusively to corporate/managerial problems. In 1968, Forrester presented an urban dynamics model in his book titled “Urban Dynamics” (1969), which was the first major non-corporate application of SD, the second major application of SD coming shortly after. In 1970, Forrester created the first draft of a System Dynamics model of the world's socioeconomic system – WORLD1. He published a refined model WORLD2 in a book titled “World Dynamics” in 1971 (http://www.systemdynamics.org/what-is-s).
Today, the SD methodology is used for numerous problems as the modelling tools were originally developed with the clear intention of facilitating the interplay between the manager’s mental models and the analyst’s formal model. With time, it seems that a huge opening has occurred and System Dynamics modelling has become a prominent useful tool in the area of public policy.

Over the past two decades, the application of SD has focused on complex systems regarding economics, management, environment and society. Specifically, its application involves a large variety of modelling, such as business process and strategy (Pierson and Sterman, 2013; Sterman, 2000), biological and health systems (Abdel-Hamid et al., 2014; Sterman, 2006), energy and environment (Yuan and Wang, 2014), public policy (Richardson and Ong, 2010, 2012) and transport systems (Shepherd, 2014).

3.2.2 Basic Elements of System Dynamics Modelling and Simulation

Dynamic simulation models are sets of equations that describe the behaviour of dynamic systems. The models study causes and effects. Given specified initial conditions and assumed behavioural parameters, these models trace the changes in key variables over time and allow the dynamic implications of the assumptions to be seen (Richardson and Andersen, 2010.).

Mathematically, the basic structure of a formal System Dynamics computer simulation model is a system of coupled, nonlinear, first-order differential (or integral) equations.

$$\frac{d}{dt} x(t) = f(x, p)$$

where $x$ is a vector of levels (stocks or state variables), $p$ is a set of parameters, and $f$ is a nonlinear vector-valued function (Richardson, 1991).
Simulation of such systems is easily accomplished by partitioning simulated time into discrete intervals of length $dt$ and stepping the system through time, one $dt$ at a time. Each state variable is computed from its previous value and its net rate of change $x'(t)$:

$$x(t) = x(t - dt) + x'(t - dt) \cdot dt$$

Much of the art of System Dynamics modelling is discovering and representing the feedback process, with stock and flow structures, time delays, and nonlinearities to help determine the dynamics system (Sterman, 2000; Richardson 2013).

3.2.2.1 Causal Loop Diagrams

In the SD method, the structure of complex systems is qualitatively mapped using causal diagrams. A causal loop diagram (CLD) is a simple map of a system with all its constituent components and their interactions. It has been used to describe basic causal mechanisms hypothesised to underlie the reference mode of behaviour over time and to create a connection between structure and decisions generating system behaviour (Richardson, 1997; Sterman, 2000).

A Causal Loop Diagram (CLD) consists of variables connected by causal links, shown by arrows. Figure 3.2 shows an example.

![Figure 3.2 Example of a Causal Loop Diagram](image)
In this example of flight frequency change, arrows denoting the causal influences link all the variables. For example, frequency of service is decided by the passenger volume and airport capacity. Each link has a polarity, indicating how the dependent variable changes when the independent variable is modified. A positive link (denoted by “+” on the arrow) implies the same direction of the effect (increase or decrease) as per its cause (increase/decrease). A negative link (denoted by “-” on the arrow) implies that if the cause increases (decreases), the effect decreases (increases) below (above) what it would otherwise have been (Sterman, 2000). For example, in Figure 3.2, the frequency provides an increase of the available seats to satisfy increased demand, while it is decreased/regulated or limited by the facility utilisation, e.g. runway. The mathematical definition of the link polarity is explained in Table 3.2.

Link polarity describes the structure of the system rather than the behaviour of the variables. That means they only describe what would happen if there were a change. CLD does not indicate what will happen.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X \rightarrow Y$</td>
<td>$\frac{dy}{dx} &gt; 0$; In the case of accumulations, $Y = \int_{t_0}^{t} (X + \ldots) dx + Y_{t_0}$</td>
</tr>
<tr>
<td>$X \rightarrow -Y$</td>
<td>$\frac{dy}{dx} &lt; 0$; In the case of accumulations, $Y = \int_{t_0}^{t} (-X + \ldots) dx + Y_{t_0}$</td>
</tr>
</tbody>
</table>

3.2.2.2 Feedback

Feedback is a process that occurs when the output of an event depends on the event’s past or future. Therefore, when any event is a part of a cause-and-effect chain and works as a loop, the event is called a feedback into itself (Morecroft, 2007). A feedback system should have a closed-loop structure that brings results from the past actions of the system back to control future action.
The actions of system agents or components can be basically of two kinds: negative and positive feedback effects. Those actions that attempt to control an organisation by introducing a balancing mode are called negative feedback (or self-correcting) effects, and those that attempt to initiate growth in a reinforcing pattern are called positive feedback (self-reinforcing) effects. Every system, from the very simple to the most complex, consists of a network of positive and negative feedbacks. A system’s behaviour arises from the combined effect or interaction of these loops. Therefore, the way that organisations respond to such actions is very important in developing and understanding a System Dynamics model.

In the example of Figure 3.2, there are two feedback loops. The positive reinforcement loop (labelled +) on the right indicates that higher frequency of flights will lead to a higher number of seats available, and the ability to satisfy a higher demand generated; thus a higher passenger volume. This, in turn, requires a higher flight frequency if the airfare and aircraft size are fixed. Thus there is a reinforcing impact.

The second feedback loop on the left is a negative feedback (or balancing and hence labelled -). The flight volume cannot increase forever, because it is limited by the airport capacity. Finally, the frequency increase will reach a balance level. It is expected when flight volume reaches the capacity level, there will be a demand for new investment on runways or serious congestion or delay at the airport.

It is important to note that it is very hard to tell whether the frequency will actually be increasing or decreasing because it is affected by two feedback loops, determined by the passenger demand and airport capacity. Therefore, the change of frequency is decided by which feedback dominates. In a complex system, all the interacted variables change over time and the behaviour of the system is determined by more than one feedbacks, so SD provide an appropriate method to find out the dominant variables leading the behaviour of the system.
3.2.2.3 Delays

Delays are a critical source of dynamics in nearly all systems. Some delays breed danger by creating instability and oscillation (Sterman, 2000). Others provide a “clear light” by filtering out unwanted variability and enabling managers to separate signals from noise. Delays are pervasive and take time to measure and report on with information. Sterman (2000) defines delay as a process whose output lags behind its input in some fashion. The time delay is either the reaction time or the lag between the decision and its effects on the state of the system. Delay in the feedback loops may create instability in the system.

3.2.2.4 Stocks and Flows

Causal Loop Diagrams (CLD) aid in visualising a system’s structure and behaviour and analysing the system qualitatively. To perform a more detailed quantitative analysis, a CLD is transformed into a Stock and Flow Diagram (SFD). Models with SFDs are usually built and simulated using computer software.

Stocks are also called accumulations or states or levels. Stocks characterise the state of the system and generate the information upon which decisions and actions are based.

Stocks give system inertia, but also create delays. A Stock variable is measured at one specific time, and represents a quantity existing at that point in time, which may have accumulated in the past. Stocks change over time and the value they possess at any time depends on the values they have had on previous times.

The Flow variables are also known as rates. A Flow variable is measured over an interval of time. Therefore, a Flow is measured per unit of time. Flow is roughly similar to a rate or speed in this sense and is directly changing the levels/stocks. Flows are essentially the same as auxiliaries and differ only in the way they are used in a model.

In Figure 3.3, the flight volume loop on the left in Figure 3.2 is translated into a Stock and Flow format. The stock and flow diagram (SFD) generally includes more detail.
than a causal loop diagram. It contains all the necessary information to determine the
dynamic behaviour of a system. In the frequency example, the flight volume is a stock
and it accumulates daily frequency of flights.

The SFD has a precise mathematical meaning. Stocks accumulate or integrate
their flows; the net flow into the stock is the rate of change of the stock. Hence, the
structure represented in Figure 3.3 corresponds to the following integral equation:

$$\text{Flight volume}(t) = \int_{t_0}^{t} \text{Flight volume}(t_0) + \text{Frequency change rate}(t) \, dt$$  \hspace{1cm} 3 - 3

Also it could be defined in the differential equation:

$$\frac{d(\text{Flight volume})}{dt} = \text{Frequency}(t)$$  \hspace{1cm} 3 - 4

In general, flows will be functions of the stock and other state variables and parameters
here, as indicated in Figure 3.2. Flow variable frequency is calculated by the following
function:

$$\text{Frequency}(t) = f(\text{Initial frequency}, \text{passenger}(t), \text{runway utilization}(t))$$  \hspace{1cm} 3 - 5
3.2.3 System Dynamics Applied to the Aviation System

Several scholars have used SD to research airports’ management. Agusdinata and Klein (2002) explained the dynamics of airline alliances and described the driving forces behind the formation of alliances. They examined the inherent stability of alliances, both internally and externally; Agusdinata and Klein (2002) found that cyclic economy, anti-trust legislation, hub airport congestion (externally); and trust mutual forbearance and multi-culturalism, network overlap and learning culture created by alliance (internally), are driving factors of stability. However, the analysis remained at a qualitative level, with SD Causal-Loop Diagrams not applied into a simulation model.

Using as example the US Commercial Aviation Partnerships, Peterson et al. (2007) described a hybrid model (including travellers, airlines, airports, airlines and airports’ suppliers, government agencies and travel and tourism entities) that evaluates effects of new security measures over the following 25 years. Their model has operated successfully, and its detailed description can guide the development of this SD.

Miller and Clarke (2007) developed a SD model exploring the relationships among airport investment, runway capacity and congestion to evaluate the strategic value of air transport infrastructure. They showed SD is an effective and appropriate methodology to be applied in modelling the different strategies in air transport infrastructure delivery. However, this study did not explore the market of airport and airlines. Suryani et al. (2010a) developed a SD model to forecast air passenger demand. Their model consists of five sub-models: airfare impact, level of service impact, GDP, population and runway utilisation. From the base model and scenario analysis, it was found that airfare, service level, GDP, population, flights volume and dwell time are important factors impacting demand; while runway utilisation is the determinant for terminal expansion. Based on this research, Suryani et al. (2012) established another model to forecast air cargo demand to assist policy-makers to decide when and how much
the airport should expand its terminal capacity, based on optimistic and pessimistic projections. These two studies investigated the relationship between air passenger and freight demand and airport capacity, including runway and terminal, to demonstrate how macro-economic factors (e.g. GDP growth) are influencing the airport demand and only evaluated the impact of demand change on airport capacity. Although they showed how the SD model is applied to forecast traffic demand and help to make decisions like capacity expansion, the interrelationship between airport and airlines have not been constructed in the models.

Kleer et al. (2008) presented a SD model to simulate strategic movements of airline companies in order to demonstrate the effects of entry and exit of airlines on a city pair under different sets of preconditions. The model was applied to a route connecting two German airports and was constituted of four subsystems: airline configuration, airline policy, airline attractiveness and demand. Scenarios were set up only based on the airline competition and market situations, to analyse the effectiveness of action that the predatory pricing is taken by increment airline against market entry under different conditions. The airport was not considered in this model.

Manataki and Zografos (2009, 2010) applied SD for aggregated airport terminal performance analysis with respect to a variety of performance metrics. Their model was based on the operation processes and their interconnections. The model only showed the time dimension and did not use the SD’s main characteristic, i.e. the system’s behaviour being decided by the dominant structures.

Minato and Morimoto (2011 and 2012) designed a SD model to analyse an unprofitable regional airport as an ecosystem. This model simulated different strategies (e.g. airport charge reductions, subsidies for the airline tickets) and evaluated their impact on the airport, the airline and the local government in terms of their financial status. However, this research is limited to unprofitable regional airports. Minato and Morimoto
(2011 and 2012) forecasted the passenger demand based on the local economy. Although the ticket price elasticity was considered in their model, only the impact of government subsidies was included in the SD, while the airport charge reduction was excluded.

Pierson (2011) explained in his PhD thesis why aggregate airline industry profits are cyclical. He built a behavioural SD model to explore the cause of the cyclicality in airlines’ earnings by analysing the airline profit with multiple negative feedback loops. This work provides a good example for building a large-scale model of the airline industry (Pierson and Sterman, 2013).

Steverink and Van Daalen (2011) employed SD approach to investigate a case study in the Netherlands. As a result of the increased ticket price after Dutch taxation was introduced, a huge number of passengers changed to depart from airports outside of The Netherlands. These passengers kept using foreign airports even after this tax was abolished. In their study, the SD model was developed to answer the question of which factors contributed to the asymmetric response of the system that the existing traditional discrete choice models cannot explain. The aim of the research was to model mechanisms of information exchange related to airport choice and simulation results showed that the development of awareness of an airport plays an important role in the asymmetric response.

3.2.4 Summary

The suitability of SD to the airport revenue problem specifications addressed in this research is confirmed through the following underlying characteristics of the method:

1. The behaviour of the airport system is decided by its structure;

2. SD consists of interacting feedback loops (e.g. sharing of non-aeronautical revenue between airport and airlines do not decrease the airport’s revenue, on the contrary,
by encouraging and allowing airlines to reduce their airfares, it increases non-aeronautical revenue derived from increasing passenger volumes);

3. SD uses a system of coupled, non-linear, first-order integral equations. The fundamental variables are rates (flow) and levels (accumulations of the rates), which vary in time. In the airport system, the total revenue (level) is a function of the landing and terminal fees (rates) through time;

4. Time delays could change the behaviour of system in SD, and they need a careful treatment (e.g. time lags between the airfare change and passenger response, which affects the passenger volume).

3.3 Data Collection

Several sources of data are required for model construction and testing. This research used secondary data, publicly available, from a number of sources, over the last 10 years, to construct a two-level System Dynamics model. Documents from the public domain, national and airport statistics were collected to create a structured repository of information. This research uses two cases studies: Perth, Western Australia and Nanjing, China. Although data availability was a determinant factor for this selection, the two airports have differing governance and market conditions, which deem them useful for testing numerous scenarios. Data sources are provided below: airport operation and revenue data; airline industry data; high-speed rail statistics; government regulation data and literature review – meta analysis.

3.3.1 Airport Operation and Revenue Data

Transport secondary statistics (e.g. passenger volume, flight information) were obtained from government sources: e.g. for Perth, Airport Traffic Data and Airlines Activity from

Airports’ official reports and statistics (e.g. Perth airport annual reports and schedule of fees and charges reports of Perth airport, available from < http://www.perthairport.com.au >; and Nanjing airport annual report, available from < http://www.njiairport.com >) provided the following:

- airport route structure and all the information regarding operating airlines (frequency, aircrafts, timetables);
- airport aeronautical charge rates (standard), concessionary rates;
- the airport market structure;
- time series data on the passenger volume and related revenues.

3.3.2 Airline Industry Data

Airfare range for every route and airline in both airports was observed from the airline websites and other online ticket websites (e.g. www.ctrip.com). The information of the airline market structure in a certain O-D market was summarised from the airport statistics and the related reports in the airline websites (e.g. Australia Qantas Airline < https://www.qantas.com > and China Southern Airline < http://www.csair.com >).

3.3.3 Aircraft Manufacturing Information

The data regarding the aircraft type, seat capacity and MTOW (maximum take-off weight) comes from technical documents of the aircraft manufacturing company (e.g. Boeing and Airbus, < http://www.boeing.com >) and the description of fleet from the airline websites (e.g. Australia Qantas Airline < https://www.qantas.com >).
3.3.4 Other Exogenous Inputs

There are many other exogenous inputs to the model: demand and price elasticity, regulation, airport-airline agreements, airport competition, airfares and non-aeronautical revenues per passenger (such as shopping in the terminal or parking). Price elasticity comes from government reports or literature review (e.g. elasticity database online from BITRE, available at <https://bitre.gov.au/tedb/tableList.aspx>; report “Estimating Air Travel Demand Elasticities” from IATA (2007); and Gillen et al. (2003)), which simulated the demand function, with history data collected in the related markets of airline, to fit the real data. The data regarding different regulations was taken from the government documents, e.g. Airport monitoring report 2009-2012 from ACCC (Australian Competition and Customer Commission), available at <http://www.accc.gov.au>; white paper and policy reports from CAAC, available at <http://www.caac.gov.cn>. The information of airport-airlines agreements was summarised from airport and airlines’ releases in their websites and from the literature (e.g. Oum and Fu, 2008, Barbot, 2009). The market share of the air transport under the competition with the other modes (like high-speed rail, HSR) was summarised from the Chinese government statistics and other market reports. The average passenger spending in terminals was calculated from Perth and Nanjing airports’ annual financial reports.

3.4 Summary

As stated above, System Dynamics approach is an appropriate method to investigate the characteristics of the airport as a multi-sided platform where numerous agents interact. Two case studies with similar traffic volume, but different market power, regulation and competition conditions were selected for comparison. Numerous secondary data sources
were collected to “calibrate” the SD model. When possible, uncertainties about the inputs in the model were considered via probability distribution.

In the following chapters, SD models based on the structure of interrelationships between the airport, the airline, passengers and the government were developed to investigate the airport revenue at two levels: 1) airport-government level; and 2) airport-airline level.
CHAPTER 4  BASE HIGH LEVEL SYSTEM DYNAMICS

MODEL FOR AN AIRPORT REVENUE SYSTEM

This chapter elaborates the relationships affecting the airport revenues and presents a general simulation model built using System Dynamics. The relevant data sources were described in Chapter 3. They reflect the whole structure of an airport revenue system. The SD model consists of five main modules: Demand, Traffic Volume, Aeronautical Revenue, Non-Aeronautical Revenue and Capacity. This chapter presents the structure of a base SD model to examine the long-term impact of price regulations on the airport revenue at the airport-government level. In this chapter, the validity of the base model is tested and then scenario analysis, comparing two case studies, is conducted to identify the main influencing factors for airport revenues under different conditions. The following Chapter 5 describes an expanded SD model useful for assessing the role of the market power and airport-airline relationships at route and airline level. Chapters 6 and 7 elaborate on different scenarios for the expanded model at the airport-airline level, to explore the impact of the competition with HSR, and the airline competition on airport revenue.

4.1 Causal Structure for the SD Model of an Airport

As indicated in the previous chapters, the SD approach responds to the characteristics of the airport as a multi-sided platform where numerous agents interact. Therefore, the airport revenue is affected by the interrelationships between the airport, the airline, passengers and the government. Figure 1.1 in Chapter 1 has already included these relationships, presenting a basic structure of the airport revenue system in the SD model. Based on this general structure, a SD model was developed to investigate airport revenue
at two levels: 1) airport-government level; and 2) airport-airline level. At the first level, the model examines the compound impact of price regulation and market power on airport revenue. Thus, this model focuses on the determinant factors at the airport-government level. Then, different scenarios are developed at the airport-airline level to find out the impact of the competition with HSR and the competition between airlines on airport revenue (the extended low-level or level 2 of the SD model presented in Chapter 5-7). Scenario development implies adding new feedback loops, changing the structure of certain loops (structure scenarios), as well as changing the value of certain parameters (parameter scenarios). Various combinations of conditions are tested with the SD model at different levels, to show possible situations for future decision-making.

This chapter illustrates the development of the base (level 1, or high-level hereafter) SD model.

4.1.1 Causal Loop Diagram (CLD) for an Airport Revenue Model

Figure 4.1 presents the basic relationships affecting airport revenues, using a CLD diagram. This diagram shows the causes and effects within the system structure. The aeronautical charge rate is affected by more than one feedback loops (see Figure 4.1):

- B1 loop - the revenue gap adjusting loop (negative) (top left of Figure 4.1): aeronautical charge rate is adjusted by the gap between the target aeronautical revenue and real aeronautical revenue. It is controlled by the government, the airport and the market and cannot increase indefinitely.

- B2 loop - the runway capacity (maximum number of flights landing and taking-off at an airport per hour) adjusting loop (negative) (top right of Figure 4.1): the airport target revenue increases when the airport capacity increases because it implies more investment and hence higher costs. However, higher aeronautical charges may have a negative impact on airport demand.
• R1 loop - the passenger volume adjusting loop (positive) (central left of Figure 4.1): more traffic volume brings more aeronautical revenue to the airport, which decreases the pressure on increasing the aeronautical charge rate; lower charge rate will lead to more passengers via the airfare when airlines pass the decrease of the airport charge to their passengers.¹

• Two additional small loops are displayed at the bottom of Figure 4.1 and they reflect the relations between demand, capacity, and number of flights, seat load factor and fleet size.

The dominant loop would decide the direction of change for the aeronautical charge and which loop is dominant depends on different conditions.

Note: blue colour highlights all feedback loops; red colour highlights main exogenous inputs.

Figure 4.1 High-Level Causal Loop Diagram for Airport Revenue Model

In the airport revenue system, the different decision-making processes, affecting the airport aeronautical charge rate, would lead to different structures of the system. To

¹ Airport charges represent a fairly minor component of airline cost. Much more important are labor and fuel. This research only focuses on the airport revenue, so these costs are not discussed. It may be simulated in the further study.
investigate the impact of price regulation on airport aeronautical charge rate at the airport-government level, the structure presented in Figure 4.1 will be modified as per Figure 4.2. Figure 4.2 (a) shows the SD base model under dual-till regime and the impact of the single-till regulation is illustrated in Figure 4.2 (b).

Note: blue colour highlights all feedback loops; red colour highlights main exogenous inputs.

Figure 4.2 Simplified Causal Loop Diagram for the Airport Revenue System
Comparing Figures 4.2 a and b, I notice that, besides the capacity feedback and other exogenous variables, the aeronautical charge rate is influenced by two feedback loops in a dual-till situation (Figure 4.2 a) and by three feedbacks under a single-till regime (Figure 4.2 b). This is because in the single-till regulation, the non-aeronautical revenues are also included when airports decide their target aeronautical revenues, potentially leading to lower aeronautical charges. This effect is explained through the interaction of these three feedback loops.

(i) Under a dual-till regime, the charge relates solely to the aeronautical revenues. If the aeronautical revenues do not recover the aeronautical costs, the charge rate should be increased, which would cause a reduction in the number of passengers, which may further decrease the total revenues, including the non-aeronautical revenues. In this regulation regime, because the airport is allowed to recover the aeronautical cost through the airport charges, the airport would be inclined to increase its investment to promote its capacity. This extra investment in the aeronautical facilities will be directly reflected in higher airport charges.

(ii) Under the single-till regime, the charge rate is not only decided by aeronautical revenues, but also by non-aeronautical revenues. There is a complementarity, or a balance between the aeronautical and non-aeronautical revenues to get the total target revenue, even if the aeronautical revenues do not cover the aeronautical costs, i.e. the cross-subsidisation exists. If the non-aeronautical revenues increase, this could lead to a reduction of the aeronautical charge rate, which is expected to bring more passengers and will further contribute to higher non-aeronautical revenues. This is a positive feedback, which could motivate the airport to charge airlines lower aeronautical fees, especially in a competitive market. Therefore, in this situation, the need for regulation is reduced to some extent.
(iii) Under airport capacity constraints, if the aeronautical charge rate decreases and airlines also pass these decreases to their passengers via airfare, the increase in number of passengers and flights could generate congestion, with the result being either a demand drop or higher charges (such as the congestion charge practised during the peak time in some airports). In the long-term, passengers experiencing congestion and high airfares may choose other available alternatives, like other airports or other transport modes. When the number of passengers falls considerably, the airport revenues will follow a similar pattern, which leads to an increase in the airport charges, and consequently regulates the level of congestion.

To sum up, the base model (high-level or level 1) is developed at the aggregate level and focuses on the global output of the airport, rather than on the routes and airlines. Based on this, a more detailed low-level (or level 2) model is explored in the scenarios developed in Chapters 5, 6 and 7, with the aim to examine the impact of competition and airport-airline relationship on the airport under differing regulations and market structure.

4.2 Model Boundary

The high-level model considers only revenues related to the traffic volume of the airport: aeronautical revenues from landing, security and terminal charges, as well as the non-aeronautical revenues from ground transport and trading/concession. Other revenues, such as rentals, are excluded from this model.

The main outputs of this model are the total airport revenue, passenger volumes and airport aeronautical charge rate. All main exogenous inputs are explained in Table 4.1. The objective is to explore how the outputs change under different values of these inputs.
Table 4.1 Main Exogenous Inputs in the SD Model (Also Highlighted in Figure 4.3)

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial average airfare</td>
<td>Average one-way airfare in the airport.</td>
</tr>
<tr>
<td>Average demand increase rate</td>
<td>This rate (%/year) is considered the effect of some macro economic factors such as GDP and population changes. Different values may be considered at different airports.</td>
</tr>
<tr>
<td>Airport–airline agreement</td>
<td>Represents the relationships between airport and airlines; they include the price discount offered to the airlines by the airport (measured in %).</td>
</tr>
<tr>
<td>Competition with other modes</td>
<td>Here, other modes refer to HSR. In the base model, it is set as a dummy/switch variable with values 0 and 1.</td>
</tr>
</tbody>
</table>
| Price elasticity                            | Demand elasticity with respect to airfare. Represents the market power of the airport and the airline.  
\[
\text{Price Elasticity} = \frac{\% \text{ Change in Demand}}{\% \text{ Change in Airfare}} = \frac{\Delta Q/Q}{\Delta P/P}
\]  |
| Time elasticity                              | Demand elasticity with respect to travel time including access time and security time (non-dimensional)  
\[
\text{Time Elasticity} = \frac{-\% \text{ Change in Demand}}{\% \text{ Change in Travel Time}} = \frac{\Delta Q/Q}{\Delta T/T}
\]  |
| Regulation                                  | Light-handed, price-cap, single-till, dual-till. Switch variables which take the value of 0 or 1, depending on the applied regulations. |
| Target rate of return                       | Target revenue/non-current assets; the airport expected rate of return on capital. (%) |
| Runway capacity                             | Maximum number of flights landing and taking-off at an airport (measured as flights per hour). |
| Seat load factor (SLF) threshold            | SLF represents the ratio of number of passengers on a flight to the capacity of the aircraft. If SLF>1, then airlines will need to increase their number of flights; if forecasted SLF <threshold, airlines may decrease the number of flights. The value of this threshold is different for various airlines, based their operating cost. |
| Average spending $ per pax                  | Average spending $ per pax includes shopping at terminal and ground transport, varying from airport to airport ($). |

4.3 Model Structure

As CLDs emphasise the feedback structure of the system, they cannot comprehensively present all the details of the system. Converting the CLDs into Stock and Flow diagrams (SFD) is necessary to pinpoint the physical structure of the model. SFD are more detailed than CLDs, to force the researcher to think more specifically about the system’s structure.
(see Chapter 3). Figure 4.3 shows the simplified SFD for the airport revenue system described above. A more detailed SFD is showed in Appendix A2.

Figure 4.3 Simplified Stock and Flow Diagram of the SD Model of the Airport Revenue
As indicated in the introduction to this chapter, the base SD model uses the following five key modules to compute the total revenue of the airport: 1) Demand; 2) Traffic Volume; 3) Airport Aeronautical Revenue; 4) Non-Aeronautical Revenue; 5) Capacity. These modules, denoted as sectors 1 to 5 in Figure 4.3, are described in more detail next. These allow us to investigate various components of the airport activity and aggregate its revenue.

4.3.1 Demand Module

In Figure 4.3, Sector 1 presents the structure of the Demand module. The output of this module is the demand, which will directly influence the airport traffic volume. The stock and flow chain of demand is constructed to illustrate how the airfare, modal competition and congestion affect the passenger demand. The structure of the demand change is modelled with the first-order information delay formulation that is common in System Dynamics (Sterman, 2000). The stock of the demand is accumulated over a certain time period, based on the demand change rate and starting with an initial demand (Equations 4–1 and 4-2).

\[
Demand(t) = Demand(t - dt) + Demand\ change\ rate \ast dt \tag{4-1}
\]

\[
Demand\ change\ rate = Demand \ast (Airfare\ effect +\ Competition\ effect +\ Congestion\ effect + Average\ increase\ rate) \tag{4-2}
\]

Initial demand is set using the airport annual average passenger volume for a starting year. As showed in Figure 4.3, passenger demand depends on the airfare (airfare effect), competition of other transport modes like HSR (competition effect, not included at level 1), airport capacity (congestion effect) and other macro-economic factors, like the local economy and population dynamics (average increase rate). Here, the average increase
rate is an exogenous input, representing the combined long-term impact of all the macro-level variables, without details of the interrelationships among these economic factors. At the airport-government level, the competition effect is also regarded as an exogenous input and its revenue impact could be estimated through price elasticities; however, the whole competition structure is constructed in detail in the Case Study for Nanjing (Chapter 6).

The airfare and the congestion effects are the % of the demand change, determined by the % of the change in airfare and travel time, as well as the price and time elasticities, respectively (see Equations 4-3 and 4-4). The elasticities are defined in Table 4.1.

\[
\text{Airfare effect} = \text{Price elasticity} \times \frac{\text{Airfare change}}{\text{Average airfare}} \quad 4 - 3
\]

\[
\text{Congestion effect} = \text{Time elasticity} \times \frac{\text{Congestion change}}{\text{Average travel time}} \quad 4 - 4
\]

Congestion leads to flight delays and additional waiting time for passengers, which will increase the total travel time. Congestion here is defined as the waiting time for each flight or aircraft before landing on the runway. The unit of congestion is hours per peak hour; that is, hours of waiting time per peak hour of traffic. Travel time is an important factor affecting the demand, especially for those time-sensitive passengers in a competitive market. How travel time is affected by the airport congestion will be explained in the Capacity Module in Section 4.3.5.

Figure 4.3 shows that the demand change rate is influenced by airfare through price elasticity. The price elasticity of demand measures the responsiveness, or sensitivity, of the demand for a good to changes in its price when other influences on demand are held constant. Similarly, for time elasticity, the demand change when congestion conditions change is considered. The definitions were explained in Table 4.1. At the airport-government level, I could assume the price elasticity as a static value, based on the airport market power, as well as the time elasticity.
There are many factors affecting the airfare change. For the needs of this high-level model, several simplifications are applied and only the effects related to airport charge are considered. The airfare change is set as a rate variable, which shows the instant flow rate influencing the total airfare, denoted as a level variable.

The formulation of airfare change rate by the airport charge implies two airline policies. One is the percentage (%) of the airport charge change that the airline passes to the passenger when the airport charge increases or decreases. If this percentage =100%, it means the airlines fully pass the change to the passengers through the ticket prices. The other policy is the time when the airlines respond to the modifications in airport charges. This is modelled by a simple delay function, which indicates the time lag from when the airport changes its charge rate to the moment when the airfares change in response.

Some other elements affecting the airfare are the competition and airport-airline relationships or agreements. They will be investigated at airport-airline level; in this high-level model, they are represented by two “blank” modules, named Competition and Airport-airline relationship. The specific structure of these modules will be illustrated in Chapters 5 and 6.

4.3.2 Airport Traffic Volume Module

In general, the traffic volume of the airport is decided by the passenger demand (see 4.3.1). The airlines schedule their flight frequencies (flights) and aircraft types (average aircraft size) according to the demand. Changes of flight and aircraft size are decided by the seat load factor (SLF) (see Sector 2 in Figure 4.3). The initial numbers of flights and aircraft sizes are derived from the historical data for each airline.

\[
\text{Seat Load Factor (SLF)} = \frac{\text{Demand}}{\text{Available seats}}
\]

\[
\text{Available seats} = \text{Flight Volume} \times \text{Average aircraft size}
\]
From relations 4-5 and 4-6, the SLF is influenced by demand fluctuations, resulted from the change of the airfares and other factors. At the same time, the airline is likely to change airfare to improve the SLF, explained in Section 4.3.1. Then, the flight volume is also affected by SLF under the restriction of airport runway capacity (runway utilisation). However, this adjustment is a long-term strategy. Similarly, airlines could adjust aircraft size based on the change of SLF led by the demand change (with a certain time lag, reflecting how quickly the airline responds to the market change). The flight volume and fleet size are therefore decided by positive and negative feedbacks. Once the flight frequency increases, this will lead to a reduction in the SLF for a certain route and/or airline. However, the total flight volume is restricted by runway capacity. Hence, it is impossible for an airline to increase its frequency continuously, especially in hub airports where the traffic volume is already close to the capacity limit. In such airports, the extra charge in peak time (congestion fee) could be applied.

In this module (Sector 2 in Figure 4.3), the output is the passenger volume at the airport. The number of passengers is calculated from the flight volume, aircraft seat capacity, and “real” or achievable SLF, as per relation 4-7.

\[
\text{Passenger volume} = \text{Available seat} \times \text{Real SLF} \quad 4 - 7
\]

When the calculated SLF (relation 4–5) is under the value of 1, the “real” SLF can take the same value as the SLF, which means that the passenger volume available is equal to the demand. However, if the calculated SLF increases to a value above 1, this means the demand is above the current available aircraft capacity provided by the airline. To satisfy this demand, the airlines must either increase their frequency or the aircraft sizes. This adjustment requires time and the available “real” SLF is limited to 1. In contrast, if the calculated SLF is below a certain value (e.g. 50%), the airlines may consider reduction of the frequency of their flights to cut unnecessary costs; because the vacant seats cannot not be stored, like other products. A variable called SLF threshold is set for this reason.
4.3.3 Airport Aeronautical Revenue Module

Airport aeronautical revenues include landing, terminal and security revenue. These are decided by aeronautical charge rate and airport traffic volume, derived from the traffic volume module (see Section 4.3.2). Several pressures influence the aeronautical charge rate: airport costs, airport-airline relationships, airport competition and regulation. At this high-level of model, only the aggregated aeronautical charge is considered, without looking into detail at each component separately. Hence, the assumption is made that the charge rate is affected by the airport cost and price regulation alone. The other effects of airport-airline relationship and competition will be discussed in Chapters 5 and 6. To summarise the three components (landing, terminal and security together), only one variable named “aeronautical charge per passenger” is used, representing the average combined charge per passenger, which changes with the different price policies. In this high-level model, historical average aeronautical revenue per passenger is assumed to the value of aeronautical charge rate per passenger.

Sector 3 in Figure 4.3 presents the structure of total aeronautical revenue, based on the average aeronautical charge per passenger. This module assists in investigating the impact of price regulation on the average charge rate.

\[
Aeronautical \ charge \ per \ pax(t) = Aeronautical \ charge \ per \ pax(t - dt) + Aeronautical \ charge \ rate \ change \ \times dt \quad 4 - 8
\]

\[
Total \ aeronautical \ revenue = Aeronautical \ charge \ per \ pax \times Passenger \ volume \quad 4 - 9
\]

The aggregated aeronautical charge rate represents the standard charge rate applied to all airlines, without price discrimination. This rate is decided by the airport costs and airport target profit/revenue, depending on the single-till or dual-till and price-cap or light-handed method. Airport costs have complex structures as well and involve varieties of
factors beyond the scope of this research. Moreover, the value of airport investment or assets relating to capacity is used to compute the target revenue via target rate of return on capital. The data of airport assets is estimated by the airport’s historical financial statistics.

Different feedbacks affect the aeronautical charge rate. The main feedback is determined by the gap between the aeronautical revenue and the target revenue.

\[
Aero\ charge\ adjustment = \frac{Aeronautical\ revenue\ gap}{Passenger\ volume}\quad 4-10
\]

\[
Aero\ charge\ rate\ change = \frac{Aeronautical\ charge\ adjustment}{Charge\ adjust\ time}\quad 4-11
\]

Thus, the airport will make the decision if it is necessary to revise the current charge rate comparing the real net revenue with the target (aeronautical revenue gap in Figure 4.3 and relation 4-10). The target aeronautical revenue is decided by the price regulation, target rate of return and airport investment or assets. What regime is applied, single-till or dual-till, is decisive. If all revenues are considered when deciding the charge rate, this implies there is a subsidy from the non-aeronautical to the aeronautical activity\(^2\).

Therefore, the charge rate is expected to be lower in comparison with the dual-till method. The target rate of return is also an important input affecting the target revenue. Although currently most airports in the world are commercial, their aeronautical operations are still regarded as a public utility. Therefore, the rate of return may be limited by government, even if the airports are under a lighted-hand regulation, as in Australia.

Another factor affecting the aeronautical charge rate is the charge adjust time. This is a time delay indicating how often the airport adjusts its charge rate. This value will influence the airport system behaviour. If the change is sporadic/seldom, the airport

\(^2\) It could be argued that some capital expenses, like terminals, parking facilities, should be financed by non-aeronautical revenues.
may face substantial deficits; nevertheless, a too frequent change (e.g., seasonal) is not a practical solution from the airport and airlines’ viewpoint.

Furthermore, if the price-capped regulation regime is applied (e.g., for an airport like Nanjing), another feedback would affect the charge rate change: the regulation feedback. In this case, the charge rate will only fluctuate under the cap value set by the regulation.

Finally, it is not uncommon that the airport applies different discount rates for different airlines and different routes. This decision is based on the specific agreement (e.g. some flag airline could get more discount) and airport competition, especially considering competition with other transport modes. In this situation, the airport may compare the airfares with the ticket prices for the competing modes on similar routes and act accordingly, in order to increase the market share of the air transport. These measures are further explored in Chapters 6 and 7.

4.3.4 Airport Non-aeronautical Revenue Module

The airport non-aeronautical revenues include the ground transport and trading revenues. At this stage, the non-aeronautical revenues are only computed considering the passenger volume and the average spending per passenger (see Sector 4 in Figure 4.3). A more detailed structure of the revenues from the ground transport and trading is investigated at the airport-airline level (in Chapters 6 and 7).

\[
\text{Non – aeronautical revenue} = \text{Passenger volume } \times \text{Average spending per pax}
\]

In the high-level model, average spending per passenger is set as an exogenous input, covering both spending in the terminal (shopping, hospitality), as well as for ground transport (taxi, public transport and car hiring).
4.3.5 Capacity Module

Sector 5 in Figure 4.3 shows that the airport capacity affects the airport demand through congestion and influences the target revenue through the required investment increases. Additionally, airlines’ decisions to increase their flight volumes are affected not only by demand, but also limited by the airport’s runway capacity. The runway capacity in this model is given in terms of flights per hour (see Table 4.1), and thus:

\[
\text{Runway utilisation} = \frac{\text{Flight volume/hour}}{\text{Runway capacity}}
\]

If the runway utilisation increases at values above 1 (or even above the practical capacity of 0.9), potential demand cannot be met by the airport. This means the number of flights cannot be increased. Obviously, high runway utilisation leads to congestion, which then affects the travel time spent by passengers in the airport. The total travel time is an important factor influencing the passenger choice, especially for business travellers and those who have a high value of time. This effect is even more prevalent when other travel alternatives are available. The function between runway utilisation and congestion (waiting time, see Section 4.3.1) used in this model is extracted from previous research (Suryani et al., 2010 a, b; Miller and Clarke, 2007; de Neufville and Odoni, 2002). On the other hand if an airport is really congested, its charges are likely to increase, so that expansion can be financed.

When the runway utilisation approaches its practical threshold, the airport will make a decision when or how to increase its capacity. This implies new investment must be added (like a new runway), which will definitely affect the airport’s costs and consequently, its target revenue (bottom of Figure 4.3). However, there is a delay (delivery time) in supplying the desired capacity, once the decision has been made to deliver it, i.e. runway construction time.
4.3.6 Summary

Figure 4.3 illustrates the relationships between airport revenue and its operation through five modules: Demand, Traffic Volume, Airport Aeronautical and Non-Aeronautical Revenues, and Capacity. Multiple feedback loops lead to changes in the aeronautical charge rate. The dominant effects are due to regulation and capacity utilisation.

4.4 Introduction of Case Studies

In this section, two airports are simulated and compared, to investigate the impact of the regulation on airport revenue. Besides data availability, there are four main reasons for choosing these two case studies: 1) Different regulation regimes between Perth Airport and Nanjing Airport; 2) Different market power, especially for Nanjing under competition with other transport mode; 3) Middle-sized airports with comparable traffic volume; 4) Important regional role of both airports (limited international activity), which are not hubs, therefore passengers travelling from origins to destinations, without many transfers. This final characteristic implies that passengers are expected to have similar shopping behaviour in the terminals. More details are presented in the following.

4.4.1 Introduction of Nanjing Airport

The Chinese air transport market has experienced substantial growth in the last 30 years. The annual growth of air passenger traffic was about 17% from 1978-2010 and about 15% during 2000-2014 (CAAC, 2010-2015). In 2013, about 0.35 billion passengers travelled by air transport. Since 2005, China’s ranking in terms of scheduled air traffic has become 2nd only exceeded by the United States. The number of civil airports increased from 94 in 1990 to 182 in 2012, and is expected to reach 244 in 2020 (CAAC, 2013; Fu et al., 2012).
Nanjing Lukou International Airport (NKG) is the main airport serving Nanjing (capital of Jiangsu province in China). It is located over 35 km south of the city centre, connected to Nanjing and neighbouring towns by freeways. NKG was opened on 28 June 1997 and the total number of total passengers handled reached 10 million in 2009. During 2006 to 2012, the average annual increase in passenger growth was around 15%. In 2013, the total aircraft movements reached 134,913 and passenger number surpassed 15 million, which represents three million above the terminal’s designed operational capacity. In 2014, a new terminal and a new parallel runway with taxiways were completed, after more than three years of construction (Nanjing Airport website: http://www.njiairport.com).

By the end of 2013, there were 45 domestic routes and 19 international routes operated by about 25 airlines in NKG. Nanjing is the hub for China Eastern Airlines Jiangsu Company, and a base city of Shenzhen Airlines. China Southern Airlines and Xiamen Airlines also operate a considerable number of flights here. Nanjing is the main base for China Postal Airlines, with pure cargo service to all major cities in China, handling express mail and cargo transportation for China Post (Nanjing Airport website: http://www.njiairport.com).

NKG is one of the important trunk airports in China. It is also the major cargo airport of the East China Region. Shanghai Hongqiao Airport and Pudong Airport are its alternative airports. NKG is also a major airport in the Yangtze River Delta area of East China, that includes eight other major airports: Shanghai Pudong International Airport; Shanghai Hongqiao International Airport; Hangzhou Xiaoshan International Airport; Ningbo Lishe International Airport; Wuxi Shuofang Airport; Changzhou Benniu Airport; Nantong Airport and Yangzhou Taizhou Airport. The average distance between airports is less than 160 km, so there is air transport competition in the area. Figure 4.4 shows the spatial distribution of the nine airports.
The map indicates that NKG is located NW, inland of the other competing airports, making good connections with central and western parts of China.

Figure 4.4 Airports near to Nanjing Airport

4.4.2 Introduction of Perth Airport

Perth Airport is located 13 km east of Perth CBD, the capital city of Western Australia (WA). Perth Airport is Australia’s fourth largest airport in terms of passenger traffic, and given its location, a gateway to South East Asia, Europe and Africa. It is the premier international, domestic and regional entry to WA for commercial aircraft, freight and passengers, and plays an important role in the state’s economy. Until now, there have been 18 international, eight domestic and regional, and four general aviation airlines operating at Perth Airport, connecting travellers to over 50 destinations around Australia and overseas (Perth Airport website: [www.perthairport.com.au](http://www.perthairport.com.au)). Figure 4.5 a shows the location and main international connection of Perth Airport and Figure 4.5 b displays the domestic interstate routes from Perth.

Perth Airport has seen strong passenger growth in the last few years, primarily due to the state's prolonged mining boom and an increase in traffic from international
LCCs. Passenger numbers have trebled in the past 10 years with more than 12.6 million people travelling through the airport in 2012. In fact, in the fiscal year ending in June 2012, Perth Airport experienced a substantial passenger growth (11.7% internationally and 6.9% domestically), resulting in an overall increase of 10.3% in demand. During July 2012-June 2013, a total of 13.7 million passengers and 151,333 aircraft movements were recorded. Based on the average growth rate, the total passenger volume is forecasted to reach 24 million by 2019 (www.perthairport.com.au).
In terms of regulation and ownership, in July 1997, Perth Airport Pty Ltd took up a 99-year leasehold interest in Perth Airport as part of the first phase in the privatisation of airports in Australia. At that moment, Perth Airport was subjected to CPI-X price cap with X efficiency level in the range of 1-5%. In 2002 the price cap was removed and light-handed regulation implies price monitoring by the Australian Competition and Consumer Commission (ACCC) was instituted. It left an opportunity for price control to be re-regulated if necessary (Forsyth, 2002, 2003b, 2007; Schuster, 2009; Littlechild, 2012; Adler et al., 2015). This light-handed regime includes following several pricing principles: 1) at an airport with capacity-constraints, price may generate revenue above long-run costs, but any additional revenues should be applied to generate additional capacity; 2) at an airport without capacity-constraints, price should generate revenues not above long-run costs on a dual-till basis; 3) price-discrimination is permitted to promote efficient use of the airport; 4) airport and airlines should operate under commercial agreements (Schuster, 2009).

Table 4.2 describes the main characteristics of NKG airport, compared to Perth Airport.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Perth Airport</th>
<th>Nanjing Airport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic Volume/Year 2013</td>
<td>Total of 13.7 million annual passengers and 151,333 aircraft movements; international traffic accounted for 29%.</td>
<td>Total of 15 million annual passengers and 134,913 aircraft movements; international traffic accounted for around 12%.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Light-hand regulation (price monitoring).</td>
<td>Rate of return (government sets price cap).</td>
</tr>
<tr>
<td>Ownership</td>
<td>Fully private for–profit via trade sale with share ownership tightly held.</td>
<td>Partially private for profit with government controlling interest.</td>
</tr>
<tr>
<td>Market Environment</td>
<td>High market power because of few substitutes and limited competition. 30-40% of revenues come from aeronautical services (2006-2013).</td>
<td>Low market power because of numerous substitutes (e.g. two airports in Shanghai, 280km; Hangzhou Airport, 310 km; Wuxi Airport, 160 km; Changzhou Airport, 110km; Yangzhou Airport, 130km, see Figure 4.4) and competitive travel alternatives (e.g. high-speed train).60-65% of the revenues from aeronautical services in 2012.</td>
</tr>
</tbody>
</table>
4.5 Simulation Model

In this section, the base SD model is verified and tested in the context of Perth Airport. Additionally, a number of different scenarios are simulated and sensitivity to main inputs analysed, with the objective to investigate the impact of price regulation on the airport revenue. This model assists with finding the role of price-related decisions made by the airport in maximising its revenue under different situations.

4.5.1 Parameter Setting

Table 4.3 Initial Parameter Values for the Two Case Studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target rate of return in aeronautical</td>
<td>22.8%</td>
<td>This rate refers to the proportion of aeronautical revenues on aeronautical assets (% of the aeronautical assets). Due to the data availability and comparison, this value is assumed based on average airports in Australia (ACCC, 2006).</td>
</tr>
<tr>
<td>revenues</td>
<td>22.8%</td>
<td></td>
</tr>
<tr>
<td>Demand elasticity with respect to</td>
<td>-1.33(^a)</td>
<td>Average elasticity for domestic routes. The value is calculated based on previous studies (IATA (2007); Gillen et al., 2003) and transport elasticities database of Australia, available at website of the Bureau of Infrastructure, Transport and Regional Economics (BITRE) (<a href="https://bitre.gov.au/tdb/tableList.aspx">https://bitre.gov.au/tdb/tableList.aspx</a>).</td>
</tr>
<tr>
<td>airfare</td>
<td>-0.86(^b)</td>
<td></td>
</tr>
<tr>
<td>Demand elasticity with respect to</td>
<td>-0.8(^c)</td>
<td>When travel time increase, the passengers will transfer to other transport modes (if available in the competitive market). (Belobaba et al., 2009).</td>
</tr>
<tr>
<td>travel time</td>
<td>-0.8(^c)</td>
<td></td>
</tr>
<tr>
<td>Spending per pax in non-aero activity</td>
<td>¥ 14 (about AUD 3)</td>
<td>Including shopping in the terminal and spending on ground transport (parking, access to airport). Other non-aeronautical revenues are assumed to be fixed.</td>
</tr>
<tr>
<td></td>
<td>AUD 8</td>
<td></td>
</tr>
<tr>
<td>Initial average airfare</td>
<td>¥ 600 (AUD 120)</td>
<td>Domestic one-way airfare across all routes.</td>
</tr>
<tr>
<td></td>
<td>AUD 400</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>--------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Annual rate of increase in demand</td>
<td>Nanjing 15% (2006-2012) Perth 11% (2003-2013)</td>
<td>Based on the airport historical data.</td>
</tr>
<tr>
<td>Regulation</td>
<td>Price-cap Nanjing Light-handed Perth</td>
<td>In Nanjing, price-cap is about ¥79 (AUD 16) per departing passenger (as the landing charge in Nanjing is per flight basis, here, the value of average charge rate per flight is converted into pax based on an assumed seat load factor of 80%)</td>
</tr>
<tr>
<td>Initial average aeronautical charge per passenger</td>
<td>AUD 7.14 per passenger Perth ¥79 (AUD 16) per departing passenger</td>
<td>Historical average aeronautical revenue per pax in 2002 for Perth and in 2006 for Nanjing.</td>
</tr>
<tr>
<td>Capacity (flights/hour)</td>
<td>39 flights/peak hour Nanjing 62 flights/peak hour Perth</td>
<td>Runway capacity (it assumes no change in capacity if no new runway).</td>
</tr>
<tr>
<td>Initial flight volume per year</td>
<td>64,591 nanjing 51,650 Perth</td>
<td>Perth in year 2002, Nanjing in year 2006.</td>
</tr>
<tr>
<td>Initial passenger volume (pax)</td>
<td>6,969,100 Nanjing 5,332,745 Perth</td>
<td>Perth in year 2002, Nanjing in year 2006.</td>
</tr>
<tr>
<td>Initial aircraft size</td>
<td>110 pax/flight Nanjing 130 pax/flight Perth</td>
<td>Weighted averages, considering the dominant fleets of the airlines operating in the airports and the average pax per flight based on airports statistics.</td>
</tr>
<tr>
<td>SLF threshold</td>
<td>100% and 50% Nanjing 100% and 50% Perth</td>
<td>When SLF &lt;50%, the airline will consider decreasing the number of its flights; when SLF&gt;100%, the airline needs to increase the number of flights.</td>
</tr>
<tr>
<td>Trading and ground transport as % of total non-aeronautical revenue</td>
<td>40% Nanjing 51% Perth</td>
<td>Based on the airports’ financial statistics.</td>
</tr>
</tbody>
</table>

a: This value is computed based on IATA (2007), which developed some general guidelines on the use and application of airfare elasticities. This study uses relevant elasticities for different situations by applying the relevant multiplier. Here, the base multiplier for market level is 1.4 and geographic multiplier for Asia (0.95).


c: Time elasticity of demand is nominally considered to be around -0.8 for leisure passengers and approximately -1.6 for business passengers ((Belobaba et al., 2009). Here, only the economy class is considered.
4.5.2 Model Verification

The high-level model is applied to Perth Airport in order for validation. In Tables 4.4 and Table 4.5, I compare the results of simulation with the airport statistics during 2002-2012.

The subscript $s$ refers to modelled or simulated data and $h$ to historical data.

Table 4.4 Simulation Results for Perth Airport 2003-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Flight, $s$ (100,000)</th>
<th>PAX, $s$ (100,000)</th>
<th>Charge rate, $s$ (AUD/pax)</th>
<th>Aero revenue, $s$ (AUD, million)</th>
<th>Non-aero revenue, $s$ (AUD, million)</th>
<th>Total revenue, $s$ (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-03</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.08</td>
<td>83.65</td>
<td>121.73</td>
</tr>
<tr>
<td>03-04</td>
<td>54,530</td>
<td>59.13</td>
<td>7.57</td>
<td>44.74</td>
<td>92.75</td>
<td>137.49</td>
</tr>
<tr>
<td>04-05</td>
<td>57,410</td>
<td>65.63</td>
<td>7.57</td>
<td>49.70</td>
<td>102.95</td>
<td>152.65</td>
</tr>
<tr>
<td>05-06</td>
<td>60,290</td>
<td>72.80</td>
<td>7.84</td>
<td>57.09</td>
<td>114.19</td>
<td>171.28</td>
</tr>
<tr>
<td>06-07</td>
<td>63,170</td>
<td>80.84</td>
<td>7.67</td>
<td>62.04</td>
<td>126.80</td>
<td>188.84</td>
</tr>
<tr>
<td>07-08</td>
<td>66,050</td>
<td>85.87</td>
<td>7.76</td>
<td>66.64</td>
<td>134.69</td>
<td>201.33</td>
</tr>
<tr>
<td>08-09</td>
<td>71,886</td>
<td>93.45</td>
<td>8.35</td>
<td>78.01</td>
<td>146.59</td>
<td>224.60</td>
</tr>
<tr>
<td>09-10</td>
<td>79,358</td>
<td>103.17</td>
<td>8.61</td>
<td>88.83</td>
<td>161.83</td>
<td>250.66</td>
</tr>
<tr>
<td>10-11</td>
<td>87,710</td>
<td>114.02</td>
<td>9.13</td>
<td>104.11</td>
<td>178.86</td>
<td>282.97</td>
</tr>
<tr>
<td>11-12</td>
<td>96,908</td>
<td>125.98</td>
<td>9.53</td>
<td>120.11</td>
<td>222.32</td>
<td>342.43</td>
</tr>
<tr>
<td>12-13</td>
<td>107,133</td>
<td>139.27</td>
<td>11.39</td>
<td>158.61</td>
<td>273.08</td>
<td>431.69</td>
</tr>
</tbody>
</table>

*For data comparability and availability, in this high-level model, average aeronautical revenue per passenger is assumed as the value of aeronautical charge rate per pax.

Table 4.5 Perth Airport Statistics from 2003-2013

<table>
<thead>
<tr>
<th>Year</th>
<th>Flight, $h$ (100,000)</th>
<th>PAX, $h$ (100,000)</th>
<th>Charge rate, $h$ (AUD/pax)</th>
<th>Aero revenue, $h$ (AUD, million)</th>
<th>Non-aero revenue, $h$ (AUD, million)</th>
<th>Total revenue, $h$ (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-03</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.10</td>
<td>56.50</td>
<td>94.60</td>
</tr>
<tr>
<td>03-04</td>
<td>52,998</td>
<td>60.39</td>
<td>7.42</td>
<td>44.80</td>
<td>71.70</td>
<td>116.50</td>
</tr>
<tr>
<td>04-05</td>
<td>56,118</td>
<td>66.56</td>
<td>7.65</td>
<td>50.90</td>
<td>89.90</td>
<td>140.80</td>
</tr>
<tr>
<td>05-06</td>
<td>59,442</td>
<td>71.35</td>
<td>8.04</td>
<td>57.40</td>
<td>108.10</td>
<td>165.50</td>
</tr>
<tr>
<td>06-07</td>
<td>60,515</td>
<td>80.89</td>
<td>8.13</td>
<td>65.80</td>
<td>107.00</td>
<td>172.80</td>
</tr>
<tr>
<td>07-08</td>
<td>69,237</td>
<td>91.79</td>
<td>8.12</td>
<td>74.50</td>
<td>107.10</td>
<td>181.60</td>
</tr>
<tr>
<td>08-09</td>
<td>81,238</td>
<td>97.35</td>
<td>9.11</td>
<td>88.70</td>
<td>129.30</td>
<td>218.00</td>
</tr>
<tr>
<td>09-10</td>
<td>86,840</td>
<td>104.64</td>
<td>9.07</td>
<td>94.90</td>
<td>172.30</td>
<td>267.20</td>
</tr>
<tr>
<td>10-11</td>
<td>91,723</td>
<td>114.51</td>
<td>9.42</td>
<td>107.90</td>
<td>202.00</td>
<td>309.90</td>
</tr>
<tr>
<td>11-12</td>
<td>100,277</td>
<td>126.33</td>
<td>9.55</td>
<td>120.70</td>
<td>245.60</td>
<td>366.30</td>
</tr>
<tr>
<td>12-13</td>
<td>110,654</td>
<td>136.64</td>
<td>11.75</td>
<td>160.50</td>
<td>247.80</td>
<td>408.30</td>
</tr>
</tbody>
</table>
T-tests indicate that the results of the SD model are indistinguishable from the statistics (aeronautical revenues $p=0.616$, non-aeronautical revenues $p=0.750$, and total revenues $p = 0.737$), thus the simulation is robust and results reliable.

Figure 4.6 shows graphically the annual changes in flights, passengers, and revenues, by comparing the simulation results with the statistics over a 10-year period. Again, results presented in Figure 4.6 indicate that in the case of Perth Airport the simulation matches the historical data.
Figure 4.6 (c) Comparison of Charge Rate

Figure 4.6 (d) Comparison of Annual Aero Revenue

Figure 4.6 (e) Comparison of Annual Non-aero Revenue (AUD)
4.5.3 Scenario Settings

1) Nanjing Airport

Scenario 1 Impact of regulation on the airport revenue

Chapter 1 identifies that there are different types of regulation regimes. Currently Nanjing Airport is applying price-cap and dual-till regulation regime (CAAC, 2007), which means the maximum charge rate of the airport is decided by the government. As stated in Chapter 2, there is an argument about which regulation is better. Simulating the impact of different regulation on the traffic volume, the airport aeronautical charge and the airport revenue data is useful in order to find out the direction of airport revenues and relative contribution of regulation to the charges.

Comparison of the four different regulation regimes is presented in Figure 4.7 (all the numerical results are seen in Table A4.1 and 4.2 in Appendix A4). Because of the data availability, the simulation of Nanjing Airport runs from 2006-2012. For simulation, the same rate of return of aeronautical revenue (22.8%, see Table 4.3) is applied in Nanjing and Perth, to find out the impact of the different regulations. The same price-cap
is assumed under single-till and double-till regulations in order to compare the results under same conditions, although it is not realistic.

Case 1 - Light-handed & dual till. Assumed rate of return=22.8%;

Case 2 - Light-handed & single-till. Assumed rate of return=22.8%;

Case 3 - Price-cap & dual-till. Assumed price-cap = ¥ 79 (AUD 16) \(^3\) per departing passenger;

Case 4 - Price-cap & single-till. Assumed price-cap = ¥79 (AUD 16) per departing passenger.

---

\(^3\) See Table 4.3
Figure 4.7-c Impact on the Aeronautical Charge Rate

Figure 4.7-d Impact on Non-Aero Revenues

Figure 4.7-e Impact on Aeronautical Revenues
Figure 4.7 shows the results of dual-till regulation are the same (case 1 and case 3), and results of single-till are the same in cases 2 and case 4, no matter light-handed or price-cap applied. This is because the price-cap value is set above the adapted rate of return I set (22.8%), which means the charge rated based on 22.8% is less than our assumed price-cap (¥79 per departing passenger).

It is indicated in Figure 4.7 that the charge rate in dual-till regulation is higher than single-till regulation at the same rate of return of aeronautical revenue. It seems that single-till is beneficial to the passengers, however aeronautical revenue is influenced much more by charge rate than the passenger volume (comparing Figure 4.7b, c and e). Therefore, the total airport revenue is lower under a single-till regulation than that of dual-till one (Figure 4.7f), because it is positively affected by the charge rate.

It is also clear that the passenger volume is negatively affected by the charge rate (passenger volume in cases 1&3 under dual-till is higher than in cases 2&4 under single-till), although the difference impact is minimal. This means that the airport traffic volume is mainly decided by market/exogenous factors, and limited by the airport capacity.
Therefore, the airport is unlikely to increase its revenue through more passengers brought by lower aeronautical charges.

As already indicated, in China, the price-cap is set by the general Administration of Civil Aviation of China, CAAC, responsible for the national aviation affairs. CAAC sets the charge rate for different airports based on three classes, depending on the airport traffic volume. The standard charge rate is calculated by the average rate of return of the similar airports. Here, for NKG, the rate of return is calculated to about 28% by the assumed price-cap (¥79 per departing passenger).

Next, I investigate scenarios when the airport charges the airlines price-cap value, excluding any competition with other airports or other transport modes. The results of the simulation are presented in Table 4.6.

The results confirm that higher charge rates bring higher revenues to the airport (Table 4.6 - price cap, compared with Figure 4.7 - lighted-handed regulation). When comparing the aeronautical revenues in both cases with the historical data of Nanjing Airport (see Table 4.7), it is found that the result of applying the price-cap regulation is closer to the historical data and higher than the revenues for light-handed regulation. This suggests that in a market without any competition, NKG would prefer to charge maximum charge rate to the airlines, in order to get more revenues. The analysis of the impact of competition (in NKG with another transport mode) is done in Chapter 6.

Table 4.6 Simulation Results of Applying Price-Cap Charge Rate (¥ 79 per Departing Passenger)

<table>
<thead>
<tr>
<th>Year</th>
<th>Flight,</th>
<th>Pax,100,000</th>
<th>Charge rate, (¥/pax)</th>
<th>Aero revenue, (¥, million)</th>
<th>Non-aero revenue, (¥, million)</th>
<th>Total revenue, (¥, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>64,591</td>
<td>69.69</td>
<td>79</td>
<td>275.28</td>
<td>243.92</td>
<td>519.20</td>
</tr>
<tr>
<td>2007</td>
<td>67,471</td>
<td>74.22</td>
<td>79</td>
<td>293.16</td>
<td>259.76</td>
<td>552.92</td>
</tr>
<tr>
<td>2008</td>
<td>91,902</td>
<td>92.16</td>
<td>79</td>
<td>364.05</td>
<td>322.58</td>
<td>686.63</td>
</tr>
<tr>
<td>2009</td>
<td>94,782</td>
<td>104.26</td>
<td>79</td>
<td>411.83</td>
<td>364.91</td>
<td>776.74</td>
</tr>
<tr>
<td>2010</td>
<td>103,888</td>
<td>114.28</td>
<td>79</td>
<td>451.39</td>
<td>399.97</td>
<td>851.36</td>
</tr>
<tr>
<td>2011</td>
<td>134,366</td>
<td>140.13</td>
<td>79</td>
<td>553.52</td>
<td>490.46</td>
<td>1043.97</td>
</tr>
<tr>
<td>2012</td>
<td>137,246</td>
<td>150.97</td>
<td>79</td>
<td>596.33</td>
<td>528.40</td>
<td>1124.73</td>
</tr>
</tbody>
</table>
Table 4.7 Comparison of the Aeronautical Revenues under Different Charge Rate Regimes (¥ Million).

<table>
<thead>
<tr>
<th></th>
<th>Case 1 Light-handed regulation</th>
<th>Case 2 Price-cap charge rate applied</th>
<th>Case 3 Historical data of Nanjing</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>251.18</td>
<td>364.05</td>
<td>375.67</td>
</tr>
<tr>
<td>2009</td>
<td>253.99</td>
<td>411.83</td>
<td>422.60</td>
</tr>
<tr>
<td>2010</td>
<td>277.48</td>
<td>451.39</td>
<td>514.63</td>
</tr>
<tr>
<td>2011</td>
<td>375.17</td>
<td>553.52</td>
<td>538.08</td>
</tr>
<tr>
<td>2012</td>
<td>472.32</td>
<td>596.33</td>
<td>596.51</td>
</tr>
</tbody>
</table>

2) Perth Airport

Scenario 1: Impact of regulation on the airport revenue

Currently, a light-handed and dual-till regime is applied to Perth Airport, which means that the charge rate of the airport is monitored by the government. The same rate of return (22.8%) is applied in Perth to ascertain the impact of regulations. The simulation of Perth Airport runs from 2002-2012. Again, four cases are compared:

Case 1 - Light-handed & dual till. Assumed rate of return = 22.8%;
Case 2 - Light-handed & single-till, Assumed rate of return = 22.8%;
Case 3 - Price-cap & dual-till. Assumed price-cap = AUD 10;
Case 4 - Price-cap & single-till. Assumed price-cap = AUD 10

The comparison of the different impact of regulations is showed in Figure 4.8. Numerical results are listed in Tables A4.3 - A4.6 in Appendix A4, combined by pricing strategy.

Figure 4.8-a Impact on the Annual Volume of Flights
Figure 4.8-b Impact on the Annual Passenger Volume

Figure 4.8-c Impact on Aero Charge Rate

Figure 4.8-d Impact on Non-Aero Revenues
Figure 4.8 Comparison of the Different Regulations on Perth Airport Traffic and Revenues

Figure 4.8 shows that the passenger volume and non-aeronautical revenues remain almost the same under different regulations. Yet, it is clear that the traffic volume (flight volume 4.8a and passenger volume 4.8b) is negatively affected by the charge rate (volume of flights are higher in cases 1 and 3 than in cases 2 and 4 with lower charge rate), while the total revenue is positively associated with to the charge rate. Comparing the impact of regulation on the charge rate, I find the charge rate in dual-till regulation is higher than that of single-till, except for the last two years. This is because there was not substantial
investment during 2002-2010 in Perth Airport, until 2011 when a new terminal began its construction.\footnote{In Perth Airport, a new investment - terminal T3 – started in 2011, aims to not only assisted the airport with their core business (improvement in allocation of passenger flow and gates in terminal), but also has led to substantial increases of non-aeronautical revenues, through the variety of retail and hospitality facilities it has since offered. However, its benefit is a long-term impact and, in the future, if higher non-aeronautical revenues can be obtained from the same investment, the airport could successfully apply single-till regulation and bring more benefit to the passengers. This could be investigated in the future research using this model when more data will be available.}

I can conclude that the single-till regulation favours the airlines and passengers with the low charge rate, but it does not show benefits for the airport (see Figure 4.8-d). Looking into the recent years’ reports for Perth, there is substantial investments since 2011 due to the new terminal. This resulted in high costs that are expected to be recovered through the revenues, but little positive impact on the capacity because no new runway is built. In such situation, if single-till regulation is applied and the increase in non-aeronautical revenue is limited, the charge rate may be higher than for dual-till regulation.

After simulating the impact of regulations on Nanjing Airport and Perth Airport, it is concluded that for a medium size airport without competition (as indicated, competition is excluded in this high-level model), the airport would prefer to apply dual-till regulation and charge higher charge rates to the airlines in order to get higher revenues. Therefore, government regulation is necessary in such situations. Whereas this chapter focused on airport-government relationships, the following chapters investigate relationships between the airport and airlines at route level.
CHAPTER 5   EXPANDED MODEL

This chapter expands the base *high-level* model built in Chapter 4 to incorporate the airport-airline interrelations. The analysis is conducted at the route level, with the aim to explore how the airport makes price decisions to optimise its revenue. These decisions involve airline and route price discrimination, based on the traffic the carriers bring to the airport. Further airport competition and airline competition is examined in Chapters 6 and 7.

5.1 Purpose of the Expanded Low-Level Model

Chapter 4 built up a base *high-level* model to examine the long-term impact of price regulation on airport revenue at the airport-government level. In this chapter, the aggregated model is expanded at the airline and route level. Because of its finer resolution (the system is examined from a “lower-altitude”, as opposed to the “high-altitude” view adopted in the previous chapter), this model is also called a *low-level* or *level-2* model. The detailed structure allows for investigation of the interrelationships between airlines and airport and exploration of price decisions made by the airport. Furthermore, the structure enables an assessment of the impact of airport competition with other modes and the airline competition (e.g. LCC) on different routes. Finally, the benefits to the airport from non-aeronautical activities in the terminals and the role of ground transport can also be assessed.

5.2 Low-Level Model Structure

The *level 2* model includes the same five key modules as the *high-level* model: 1) Demand; 2) Traffic Volume; 3) Airport Aeronautical Revenue; 4) Non-aeronautical Revenue, and
5) Capacity, as denoted in Figure 4.3. Each of these modules represents a specific component of the airport activity and modules 3 and 4 aggregate the revenue. However, in this chapter, the level 2 model is built at the airline and route level. Accordingly, although the basic structure and relationships are the same as in the high-level model, new modules (e.g. airport competition with other transport modes) are added, which makes the stock and flow diagram different from Figure 4.3. Since this level 2 model is designed to be used for short-term analysis (1-2 years), some variables could be considered constant, such as airport capacity and its assets. These simplifications mean that the capacity module remains unchanged from that presented in Chapter 4 and at this low level, the time unit is different. Whereas the level 1 model is run on a yearly basis, the level 2 model is run by day. Time unit provides the denominator of the units-of-measure for all of the flows/rates in the model. For example, in the high-level model, the unit of demand change is % per year, while that of low-level is % per day.

Also, since the level 2 model focuses on airlines and routes, the main variables from the level 1 model become arrays or matrices, e.g. frequency or charge rate are function of the route and airline.

Given its level of detail, the low-level model provides useful information to analyse airport policies based on different routes and airlines.

5.2.1 Demand Module

Figure 5.1 shows the structure of the Demand module. The output of this module at level 2 is the daily demand, in contrast with yearly demand in the high-level model. As the daily demand of the airport fluctuates in response to compound seasonality (summer versus winter, weekday versus weekend), its calculation is done as a product between the initial daily demand and the demand change. The initial daily demand here is set using the airport daily average passenger volume, derived from historical data. This, in turn, is
determined by multiplying the airport daily frequency of flights (scheduled) with the seat capacity per flight and the average load factor (see relations 5-3 and 5-4). Therefore, the daily demand can be calculated for each airline and each route as:

\[
Demand(t) = Demand(t - dt) + \int Daily\ demand\ dt
\]

\[
Daily\ demand = Initial\ daily\ demand \times (1 + Demand\ Change)
\]

Figure 5.1 Simplified Stock and Flow Diagram of the Demand Module

As described in Section 4.3, the passenger demand is changed as a combined effect of the airfare, competition with other modes, congestion conditions and macro-economic factors e.g. GDP, population and lifestyle (average increase rate in Equation 4-2). However, in level 2 model, since the time unit is day, the effect of macro-economic factors on the daily demand is negligible. Therefore, only three effects decide the demand change in the level 2 model: airfare effect, competition effect (competition with other transport modes) and the congestion effect.

In the short-term, the demand change is triggered by the airfare change or the entry of other transport modes, through the corresponding elasticities. The value of price elasticity in this chapter is same with those of Chapter 4 (see Table 4.3 in Section 4.5.1).
A time lag or delay is set to represent the time the passengers require to respond to any change in prices, which then leads to a change in demand.

Congestion in the airport (e.g. runway or terminal facilities used at capacity) may reach a point beyond which further growth is not possible. This effect is included in the module as a % decrease of the demand. Hence, travellers may experience higher waiting time (and higher door-to-door time), which negatively impacts on the demand level (Czerny and Zhang, 2015).

All the inputs for the Demand module are given in Table 5.1.

Table 5.1 Inputs in the Demand Module

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airport charge change</td>
<td>The output of the aeronautical revenue module (see Section 5.2.3).</td>
</tr>
<tr>
<td>Initial daily frequency; Initial seat capacity; Average load factor; Season factor</td>
<td>Necessary to calculate the initial daily demand. The aggregate of a time period (e.g., previous year of operation) is used to represent the initial values of the model.</td>
</tr>
<tr>
<td>Initial airfares</td>
<td>Initial airfares for every route and airline, assumed from historical data.</td>
</tr>
<tr>
<td>Price elasticity of demand</td>
<td>Based on the different market power of the airport (in absolute value higher than 1 in Nanjing and lower than 1 in Perth. The average value of price elasticity in this chapter is same with those of Chapter 4 (see Table 4.3 in Section 4.5.1)).</td>
</tr>
<tr>
<td>Congestion effect</td>
<td>Indication of the capacity utilisation of the airport. High utilisation of the runways leads to the change in demand*.</td>
</tr>
<tr>
<td>Airport competition</td>
<td>See Chapter 6</td>
</tr>
<tr>
<td>Airline pass percentage (APP)</td>
<td>The proportion in which the airline changes the airfare when the airport is charge changed. E.g. 100% means the airline fully passed the change of airport charge to the airfare; 0 means the airline does not change the airfare.</td>
</tr>
</tbody>
</table>

* Note: Although none of the airports examined here are seriously congested and/or subject to a slot coordination process, the structure of the model enables consideration of short-term situations when demand for facilities exceeds availability.

In this chapter, the impact of airfare and congestion on the demand is simulated, while the competition effect will be investigated in the case studies in Chapter 6.
5.2.2 Airport Traffic Volume Module

As showed in Section 4.3.2, the airport traffic volume is determined by the demand. In the level 2 model, the focus is on the daily traffic volume. The main structure and relationships are the same as in the high-level model (see Sector 2 in Figure 4.3), with the distinction that each airline and route is now modelled separately.

The initial frequency and aircraft types (by route and airline) are based on the airport schedule of flights, concordant with the historical data on demand. In the model, a graphic function (based on the industry technology data) is built to set the relation between aircraft type and its seat capacity.

\[
\text{Seat load factor} = \frac{\text{Daily Demand}}{\text{Frequency} \times \text{Seat available per flight}}
\]

This leads to a seat load factor, which may indicate whether the number of flights is too high (e.g. SLF<0.5) or too low (SLF>1). Consequently, when the demand changes, airlines can adjust their frequency and aircraft types based on SLF.

The output of the module - the daily passenger volume for a route and an airline is affected by the airline frequency, aircraft seat capacity and “real” SLF, which is calculated in relation 5-4. The difference between the “real” SLF and SLF determined above is that the latter could be over 1 (1= theoretical capacity), whereas the “real SLF” is constrained (<=1). The total passenger volume is then cumulated daily, monthly, and annually.

\[
\text{Daily passengers} = \text{Frequency} \times \text{Seat available per flight} \times \text{Real SLF}
\]

Figure 5.2 represents the stock and flow diagram of the airport traffic volume module.

The structure is similar to the Stock and Flow Diagram in Figure 4.3, with only one substantial change. The runway utilisation included in the low-level model ensures that airport facilities are not used over their capacity. If the runway reaches its capacity, the airlines cannot increase their flight numbers, but, potentially, can adjust their fleets to
accommodate a higher demand. This utilisation affects the congestion component from Figure 5.1. When the increase in flight frequency is possible, this is viewed positively, as it creates the opportunity to offer travellers services closer to their preferred time, thus additional flexibility (Czerny and Zhang, 2015).

![Figure 5.2 Simplified Stock and Flow Diagram of the Traffic Volume Module](image)

The module inputs are described in Table 5.2.

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily demand</td>
<td>The output of the demand module (see Section 5.2.1)</td>
</tr>
<tr>
<td>Initial flight frequency</td>
<td>Airline daily scheduled flights (from historical data)</td>
</tr>
<tr>
<td>Initial aircraft size</td>
<td>Aircraft maximum number of seats (by type of aircraft)</td>
</tr>
<tr>
<td>Runway utilisation</td>
<td>The output of Capacity module (see Section 5.2.5)</td>
</tr>
</tbody>
</table>

5.2.3 *Airport Aeronautical Revenue Module*

The *high-level* model (see Section 4.3.3) aggregated the airport aeronautical revenues. However, as already mentioned, they include landing, terminal and security revenues. The aeronautical revenues depend on the charge rate and the airport traffic volume,
derived from the traffic volume module (see Section 5.2.2). In this chapter, the structure of the revenues is developed in greater detail.

Figure 5.3 displays the Stock and Flow Diagram of the aeronautical revenue module. The output is the daily aeronautical revenue, which is the sum of the landing, terminal, and security revenues.

This structure appears much simpler, as the decision between single and dual-till pricing is exogenous to the module (the timescale for change in the landing charges is different from the timescale for daily operation adjustments). However, it has more links compared to Sector 3 (Figure 4.3), as it aggregates three revenues.

As explained in Section 4.3.3, the aeronautical charge rate is adjusted by the gap between the airport revenue and the target revenue (feedback decided by the regulation regime and the airport investment/cost). At the end of each year, the airport decides whether it is necessary to revise the current charge rate (published standard charge rate) by comparing the real net revenues with the target profit. I have already indicated that, depending on the regime, the non-aeronautical revenues of the airport are included or not. If all revenue sources are considered when deciding the charge rate, there is a subsidy
from the non-aeronautical to the aeronautical activity. Therefore, the charge rate may be relatively low compared with the dual-till method.

Figure 5.4 details one of the three separate revenue modules: landing. Because the other two components (terminal and security revenue) have a similar structure, they are not replicated.

Section 4.3.3 explained that airports may charge airline landing fees in two different ways: 1) on a per passenger basis, e.g. Perth Airport; or 2) on maximum taking off weight (MTOW) of the aircraft, e.g. Nanjing Airport. Nevertheless, they apply the terminal and security charges only based on a per passenger basis (Czerny and Zhang, 2015).

The landing revenue is the key component of the aeronautical revenue. To account for the two methods used in determining landing fee, two switch variables (passenger standard and MTOW standard in Figure 5.4), with values of 1 or 0, are incorporated, to match the different airport strategies.

\[ \text{Daily landing revenue} = \text{Landing charge rate} \times (\text{Passenger standard} \times \text{Daily pax} + \text{MTOW standard} \times \text{Daily flights}) \]
\[
\text{Daily terminal revenue} = \text{Terminal charge rate} \times \text{Daily pax}
\]
\[
\text{Daily security revenue} = \text{Security charge rate} \times \text{Daily pax}
\]

In the high-level model, the airport charge was applied to all airlines and routes without difference. Nevertheless, it is not uncommon that for an airport to charge different rates for different routes and different airlines, according to the airport-airline agreements/relationships and the existing competition. These effects are incorporated into the low-level model through two variables: standard charge rate (published by the airport) and the charge rate discount, as shown in relation 5-8.

\[
\text{Charge rate} = \text{Standard charge rate} \times \text{Charge rate discount}
\]

The standard charge rate is the official rate published by the airport periodically and is equal to all the airlines. It is decided by the airport cost and airport target profits/revenues and depends on the single-till or dual-till calculation method, or by the government. Because the landing charge considers both number of passengers and number of flights, the standard landing charge rate is calculated as follows (relation 5-9).

\[
\text{Standard landing charge rate} = \begin{cases} 
\text{standard landing charge rate per flight, if MTOW standard} = 1 \\
\text{standard landing charge rate per pax, if passenger standard} = 1 
\end{cases}
\]

where, MTOW and passenger standard are switch variables taking the values 0 and 1, depending on which method is applied (same as relation 5-5).

On the other hand, the discount on the charge rate is determined by the relationship (agreement) between the airport and airlines (e.g. some flag airlines could get more discount) or by the airport strategy to address competition with other airports or other transport modes (e.g. HSR). In the latter situation, the airport must compare airfares with ticket prices for other modes on similar routes and act accordingly, in order to maintain or increase its market share. The detailed effect of competition on airport charge rate will be discussed in Chapter 6.

All the inputs of the Landing Revenue module are listed in Table 5.3.
Table 5.3 Inputs in the Landing Revenue Module

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The volumes of daily passengers and daily flights</td>
<td>The output of the traffic volume module (see Section 5.2.2).</td>
</tr>
<tr>
<td>Charge rate discount</td>
<td>Discounted rates established as part of the airline – airport agreements (contracts between airport and airlines, e.g. landing fee discount, terminal rent).</td>
</tr>
<tr>
<td>Regulation</td>
<td>The impact of regulation on the charge rate, depending on which regime is applied (e.g. light-handed and price cap, single-till or dual-till, measured with dummy or switch variables, taking values of 0 and 1).</td>
</tr>
<tr>
<td>Airport competition</td>
<td>The competition with other airport or modes (e.g. HSR, measured with dummy or switch variables, taking values of 0 and 1).</td>
</tr>
<tr>
<td>Initial standard landing charge rate</td>
<td>Current published landing charge rate by the airport (per pax or MTOW).</td>
</tr>
<tr>
<td>Revenue gap</td>
<td>The gap between the target revenue and real airport revenue; the calculation of the target revenue was presented in Section 4.3.3.</td>
</tr>
</tbody>
</table>

5.2.4 Airport Non-aeronautical Revenue Module – Revenue from Trading and Ground Transport

In the high-level model, the trading revenue has been computed by multiplying the passenger volume by the average spending per passenger (including shopping at terminal and ground transport; see Section 4.3.4). Here, airport non-aeronautical revenues related to the passenger volume are differentiated between ground transport and trading revenues (as indicated in Figure 4.3). The output of this module, the non-aeronautical revenue, is simply determined as the sum of ground transport revenue and trading revenue. The calculation of trading revenue is kept simplified as average spending at terminal multiplied by passenger volume, considering that the relationship between the passenger types and their shopping preference in terminals remains beyond the scope of this study.

The ground transport revenue aggregates proceeds from: i) parking; ii) car hiring; and iii) taxi and limousines. The calculation of each of three components is described in relations 5-10 to 5-12.
Daily parking revenue

\[ \text{Daily parking revenue} = \text{daily pax} \times \text{car parking market share} \times \left( \text{short term parking charge rate} \times \% \text{ of short term parking pax} + \text{long term parking charge rate} \times \% \text{ of long term parking pax} \right) \]

5 – 10

Daily revenue from car hiring

\[ \text{Daily revenue from car hiring} = \text{daily pax} \times \text{car hiring market share} \times \text{car hiring charge rate} \]

5 – 11

Daily revenue from taxi and limo

\[ \text{Daily revenue from taxi and limo} = \text{daily pax} \times \text{taxi and limo market share} \times \text{charge rate for taxi and limo} \]

5 – 12

Figure 5.5 shows the stock and flow diagram of the Ground Transport Revenue component.

![Figure 5.5 Simplified Stock and Flow Diagram of Ground Transport Revenue](image)

Depending on their charge rates, there is some competition among these three travel modes, expressed in the current model via the market share. For simulation, the parking
charge rate is considered to follow a normal distribution around the average passenger spending on parking. Charge rates for car hiring and taxi and limousine services (used in the mathematical relations 5-11 and 5-12) are considered fixed in this module. Normally, the airport charges parking fees on time/duration, while charges to the companies of car hiring and taxi and limo are set as a % of their revenue.

The inputs for this module are presented in Table 5.4.

Table 5.4 Inputs for the Ground Transport Revenue Component

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The volume of daily passengers</td>
<td>The output of the traffic volume module (see Section 5.3.2).</td>
</tr>
<tr>
<td>Market share of each mode</td>
<td>The competition among all modes of ground transport (expected as %).</td>
</tr>
<tr>
<td>Charge rate of each mode</td>
<td>Published charge rates (e.g., AUD 6/pax short-term car parking in Perth, ¥25/pax or AUD 5 for public transport in Nanjing).</td>
</tr>
<tr>
<td>Percentage of short-term parking and long-term parking</td>
<td>Calculated from historical parking statistics (expected as %).</td>
</tr>
</tbody>
</table>

5.2.5 Capacity Module

In the air transport market without any competition from other airports or modes, the overall effect of congestion on the passenger demand is reduced, as passengers mainly change between airlines serving or operating at the same airport. Moreover, the decision of an airport to increase its runway capacity is considered a medium-long term decision and thus it does not affect daily operation (Sector 5 in Figure 4.3). Therefore, even if the congestion module is designed, the congestion effect is considered negligible here.

5.3. Simulation Settings and Results

A total of 30 simulations have been run to test the model’s boundaries and its validity,

---

5 At the moment, none of the two cases experience much congestion conditions, thus the module may appear redundant.
using case data from Nanjing Airport.

5.3.1 Parameter Setting

The initial conditions and the probability distribution functions investigated in the level 2 model are presented in Table 5.5.

Table 5.5 Parameter Values in the Two Case Studies

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLF monthly index</td>
<td></td>
<td>Monthly pax/ monthly average pax over one year. The seasonality index reflects the specifics of the airport operation.</td>
</tr>
<tr>
<td>N (1.33, 0.2)</td>
<td>N (-0.86, 0.1)</td>
<td>Elasticity for domestic routes (point estimate and standard deviation)</td>
</tr>
<tr>
<td>Spending in terminal per pax</td>
<td>11 ¥ (about AUD 2.5)AUD 3.72</td>
<td>Average value from historical data in 2011. Triangular probability density functions are set with ranges ¥ 9-13 and AUD 3 - 5.</td>
</tr>
<tr>
<td>Market share of modes in ground access</td>
<td></td>
<td>The model ignores the “kiss and goodbye” passengers, who are dropped-off, without parking. Average values from historical data in 2011.</td>
</tr>
<tr>
<td>Charge rate for all modes of ground access</td>
<td></td>
<td>Average values from historical data in 2011. Pdfs with charge rates varying according to N distributions considered in the sensitivity analysis; N(10, 2), N(25, 3), N(6, 1), N(17, 2).</td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>-------------</td>
</tr>
<tr>
<td>Nanjing</td>
<td>Landing: about ¥1,734 (364.1 AUD)/departing flight (in NKG, the landing fee is charged based on MTOW of aircraft); Terminal: ¥42 (8.8 AUD) / departing passenger; Security: ¥ 7 (1.5 AUD) per departing passenger (CAAC, 2007).</td>
<td>The aeronautical charge includes landing, terminal and security charge (landing charge is based on per flight (MTOW) in Nanjing airport, while based on per passenger in Perth airport). All values from historical data in 2011.</td>
</tr>
</tbody>
</table>

* The average value of price elasticity in this chapter is same as those of Chapter 4 (see Table 4.3 in Section 4.5.1).

### 5.3.2 Model Verification

In order to check the robustness of the model structure, the results obtained in the simulation of the 27 domestic routes operated by 18 airlines in Nanjing Airport were compared with the real statistics for the Airport in 2010 (see Table 5.6). These 27 domestic routes account for about 99% of the total domestic passengers.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2010</th>
<th>Simulation</th>
<th>Statistics</th>
<th>Error (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume (1000’s passengers)</td>
<td>13,087.7</td>
<td>12,530</td>
<td>4.5</td>
<td></td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>111,480</td>
<td>116,000</td>
<td>-3.9</td>
<td></td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>651.505</td>
<td>662.311</td>
<td>-1.6</td>
<td></td>
</tr>
<tr>
<td>Aero revenue (million ¥)</td>
<td>423.231</td>
<td>417.797</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Landing revenue (million ¥)</td>
<td>95.933</td>
<td>99.989</td>
<td>-4.1</td>
<td></td>
</tr>
<tr>
<td>Security revenue (million ¥)</td>
<td>45.807</td>
<td>48.940</td>
<td>-6.4</td>
<td></td>
</tr>
<tr>
<td>Terminal revenue (million ¥)</td>
<td>274.841</td>
<td>268.867</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Non-aero revenue (million ¥)*</td>
<td>234.924</td>
<td>244.515</td>
<td>-3.9</td>
<td></td>
</tr>
<tr>
<td>Trading revenue (million ¥)</td>
<td>143.965</td>
<td>148.835</td>
<td>-3.3</td>
<td></td>
</tr>
<tr>
<td>Ground revenue (million ¥)</td>
<td>90.959</td>
<td>95.680</td>
<td>-4.9</td>
<td></td>
</tr>
</tbody>
</table>

* Note: The non-aeronautical revenue in our model is the sum of two parts: trading revenue and ground transport revenue. The model was run 30 times and the averages are presented here.
Table 5.6 shows an average absolute error < 5% and these results give us confidence that the model produces valid results and can be applied to the other case study.

5.3.3 Scenario Setting

This general low-level model provides a basis of exploring how the airport makes decisions, at the airline and/or route level, aimed at increasing its revenues. The following scenarios are developed to show how the model can be applied to different situations on different airports.

1) Nanjing Airport

Among all the domestic routes, 23 routes, without or with little competition from other modes (see Figure A3.1 in Appendix A3), were selected to investigate the impact of the aeronautical charge rate on the airport revenue. The routes under competition with other modes will be analysed in Chapter 6.

As indicated in Chapter 4, in China, the General Administration of Civil Aviation of China (CAAC), sets the “price-cap for airports” depending on the traffic volume. Nanjing Airport is classified to be a second-class airport (airport traffic volume accounts for 1% - 4% of the total traffic volume of all airports) (CAAC, 2007).

It is important to note that in China, the government regulates the airfares as well – this is called the “price-cap for airfare” (CAAC, 2004). Until 2014, for every domestic route, the government set a maximum airfare for airline (the reference fare), based on a per km basis. Therefore, airlines could only decide their own fares under this direction price or at most 10% higher. Normally, airlines apply different discounts to the price cap in different markets. The standard airfares, published by the government for these 23 routes, are shown in Table 5.7. In 2014, however, CAAC announced that 100 domestic routes are to be deregulated from July 2015. Although this is yet to occur, this means that
in the future the airlines could decide their airfares on these 100 routes, based on distance and competition with HSR. The model enables this investigation, which is an area of future research.

The data in Table 5.7 highlights a large variability in the route distances, with a range in airfares of ¥1,170 (airfares between ¥660 and 1,830, corresponding to routes between 500 km to almost 2,000 km).

Table 5.7 Standard Airfare for 23 Routes in Nanjing

<table>
<thead>
<tr>
<th>Route</th>
<th>Standard (max) airfare (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changchun</td>
<td>1,460</td>
</tr>
<tr>
<td>Chengdu</td>
<td>1,540</td>
</tr>
<tr>
<td>Dalian</td>
<td>930</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>750</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>1,180</td>
</tr>
<tr>
<td>Guiyang</td>
<td>1,300</td>
</tr>
<tr>
<td>Guiling</td>
<td>1,110</td>
</tr>
<tr>
<td>Harbin</td>
<td>1,650</td>
</tr>
</tbody>
</table>

Table 5.7 Standard Airfare for 23 Routes in Nanjing (Continued)

<table>
<thead>
<tr>
<th>Route</th>
<th>Standard (max) airfare (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haikou</td>
<td>1,850</td>
</tr>
<tr>
<td>Kunming</td>
<td>1,750</td>
</tr>
<tr>
<td>Nanchang</td>
<td>660</td>
</tr>
<tr>
<td>Nanning</td>
<td>1,480</td>
</tr>
<tr>
<td>Sanya</td>
<td>1,830</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>1,380</td>
</tr>
<tr>
<td>Shenyang</td>
<td>1,460</td>
</tr>
<tr>
<td>Shijiazhuang</td>
<td>850</td>
</tr>
</tbody>
</table>

Table 5.7 Standard Airfare for 23 Routes in Nanjing (Continued)

<table>
<thead>
<tr>
<th>Route</th>
<th>Standard (max) airfare (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiyuan</td>
<td>880</td>
</tr>
<tr>
<td>Xian</td>
<td>1,080</td>
</tr>
<tr>
<td>Xiamen</td>
<td>980</td>
</tr>
<tr>
<td>Yinchuan</td>
<td>1,650</td>
</tr>
<tr>
<td>Zhangjiajie</td>
<td>940</td>
</tr>
<tr>
<td>Zhengzhou</td>
<td>690</td>
</tr>
<tr>
<td>Chongqing</td>
<td>1,280</td>
</tr>
</tbody>
</table>

In the following scenarios, the airport and airline competition are excluded and two assumptions of levels of airfares are compared: “high” (70% of the standard rate or price-cap) and “cheap” (30% of the price-cap) airfares. Table A5.1 in Appendix A5 provides the airfares for high and discounted levels.

Scenario 1a Impact of the uniform aeronautical charge rate on the airport and airlines revenue

The initial traffic volume, based on the historical statistic of Nanjing Airport in 2010, is set as the base for simulation under two airfares assumptions: high level and low level. Because aeronautical charge rate is price-capped in NKG, I firstly investigate the impact
on the total airport revenue of decreasing the charge rate, for the two different airfare levels.

Figures 5.6 and 5.7 (Tables A5.2 and A5.3, in Appendix A5) show the results of applying different aeronautical charge rates. As per Table 5.5, the simulation applied undifferentiated charge rates on all routes and airlines. The results assume an initial landing charge of ¥1,734 (AUD 364.1)/departing flight, a terminal fee of ¥42 (AUD 8.8), and a security fee of ¥7 (AUD 1.5) per departing passenger. These charges are assumed to be fully transferred to travellers through airfares\(^6\) (APP=1), decreasing or increasing them accordingly. For non-aeronautical revenues, a triangular distribution of average spending around ¥11 (2.3 AUD) and range ¥9-13, was considered based on historical data. In these scenarios, the price elasticity of demand followed an N distribution with average \(-1.33\) and standard deviation 0.2 (Table 5.5). This is based on the IATA report (2007), which summarised analysis examining fare elasticities in passenger aviation market to provide robust elasticity estimates via over 500 regression models covering a wide range of world regions.

As expected, at both airfare levels, the airport revenues will decrease and the airline revenues will rise with the increase of the number of passengers, which cannot balance off the dramatic decrease in aeronautical revenues (Figure 5.6 and 5.7). It is important to note that, in this chapter and hereafter, the total airline revenues only refer to the remaining revenues after deducting the total airport fees paid to the airport from tickets sales\(^7\). Other corresponding costs incurred by the airlines, such as fuel consumption, maintenance of the aircrafts are not considered in the model.

\(^6\) The variable called \textit{airline pass percentage} (APP) indicates how much of the airport charge the airline passes onto the passengers via the airfares (Table 5.1 and Figure 5.1). Value 1 means the charge is fully transferred (100%), while 0 means the airlines will hold these increases or decreases of the airport charge and/or support them separately from airfares.

\(^7\) In this thesis, total airline revenue = airline revenues from tickets sale – airport charges paid to the airport.
In terms of airport revenues, when the aeronautical charge rate is decreased, the total airport revenue drops, irrespective of the airfare level. However, the reduction depends on the airfare value. In the case of cheap airfares, the airport gains higher revenues (¥312 million versus ¥291 million in the case of high airfares) because of more pax by lower airfare. In relative terms, when the airport charge is reduced by 80%, airlines
obtain an increase in revenue of 6% when applying cheap airfares, compared to 3% when their airfare level is high (Tables A5.2 and A5.3, in Appendix A5). Nevertheless, for the airlines, their baseline level is low, and in the absence of other costs except for the airport charge fee, it is not possible to judge whether the airlines can afford the reduced airfares and if they break-even at 30% of the standard price-cap.

However, the reduction in airport revenues present in both cases indicates that the airport does not have any incentive to apply “airport charge specials” to the airlines if there is no external competition. This conclusion is consistent with the finding in Chapter 4.

Next, the effects on the airport revenue are investigated on the assumption that the government does not regulate the airport aeronautical charge rate and the airport is free to increase its charge rate via its market power. Under the same assumptions of Scenario 1, Figures 5.8 and 5.9 (Tables A5.4 and A5.5, Appendix A5), compare the results of increasing the airport charge rate.

As expected, increasing the charge rates brings additional revenue to the airport (Figure 5.9), although the passenger volume decreases (Figure 5.8). When the airfare level is high, it is easier to absorb the increases in airport charge within the ticket price, therefore, the changes in demand are modest and the total airport revenue is higher. In this model, the elasticity is not classified by type of passenger (business and economy). These results would be even higher if the elasticity of demand were set at a realistic level for different passengers, e.g. lower than -1.4 for low fare (discretionary) travellers and about -1.0 for high fare (business) travellers.
Figure 5.8 Nanjing Airport: Impact on Demand of Increasing the Aeronautical Charge Rate

Figure 5.9 Nanjing Airport: Impact on Revenues of Increasing the Aeronautical Charge Rate

The reduction in pax leads to a reduction in airline revenues as well. As indicated, their level is related to the ratio between the airport charge and airfare (Figure 5.9).

The conclusion is that the percentage increase in charge rate has different impacts on demand, depending on the airfare value. The airport would be better off to refrain from
substantial increases in airport charges when the airfares are low (e.g. LCCs), and to apply them wisely when the airfares are higher. Results show (Table A5.4 and A5.5, Appendix A5) that the total airport revenue will increase by 38% when the charge rate is increased by 80% and airfares are high, but only by 16% when the airfares are cheap. This can be explained by the large decrease in the traffic volume. As in the previous case of decreased airport charges, airline revenues are primarily dictated by the airfares, with a more substantial loss when airlines are charging cheap airfares and are facing higher airport charges.

Therefore, if there is no price cap, the airport should re-assess their decision of increasing the charge rate when the airfares are low, as their revenues do not increase proportionally with the charge. The charges for airlines with higher airfares and facing less elastic demand may exceed the airport’s marginal cost by substantial amounts (in order to recover full costs); compared to the low cost carriers, facing more elastic demand. The discrimination between airlines is efficient in welfare terms and is consistent with the proposition for public utilities offered many decades ago by Boiteux (1956) and Baumol and Bradford (1970). As presented in the seminal work of Baumol and Bradford (ibid.), “systematic deviations between prices and marginal costs that the theorem calls for may be truly optimal because they constitute the best we can do within the limitations imposed by normal economic circumstances” (p.280). This suggests that government regulation may be useful in NKG to ensure that the airport operates accordingly and makes optimal charging decisions in the presence of an added constraint (covering costs). The discrimination finding is consistent with the implication of Chapter 4. To increase its revenues, a nice balance is required: the airport is expected to decrease charge rate to attract more passengers, especially on LCCs, and may apply increases for high airfares (e.g., long-haul routes). Airlines’ revenues are substantially affected by increased charge rates, especially when airfares are low. This calls for additional investigation of situations
when the airport applies different price policies to different airlines. The case of LCCs flying on some routes is further discussed in Chapters 6 and 7.

**Scenario 1b Impact of the uniform aeronautical charge rate on different routes**

Scenario 1a explored the effect of uniform decreases and increases of airport charges on the overall airport revenues and airline revenues. The following analysis investigates the effect of increasing the charge rate on the airport revenues for different routes, when high (0.7 price-cap) or low (0.3 price-cap) airfare levels are applied. As the results show, for high airfare levels, airport revenues increase with the increase of the airport charge as explained in Scenario 1a, except for two routes, Nanjing-Nanning and Nanjing-Xiamen, which have the lowest SLF compared to other routes. Table 5.8 shows the initial SLF for all routes.

### Table 5.8 Initial SLF for All Routes

<table>
<thead>
<tr>
<th>Route</th>
<th>Initial SLF/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changchun</td>
<td>87.6</td>
</tr>
<tr>
<td>Chengdu</td>
<td>83.8</td>
</tr>
<tr>
<td>Dalian</td>
<td>83.8</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>81.6</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>83</td>
</tr>
<tr>
<td>Guiyang</td>
<td>84.7</td>
</tr>
<tr>
<td>Guiling</td>
<td>79.9</td>
</tr>
<tr>
<td>Harbin</td>
<td>86.7</td>
</tr>
</tbody>
</table>

### Table 5.8 Initial SLF for All Routes (continued)

<table>
<thead>
<tr>
<th>Route</th>
<th>Initial SLF/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haikou</td>
<td>86.3</td>
</tr>
<tr>
<td>Kunming</td>
<td>86.9</td>
</tr>
<tr>
<td>Nanchang</td>
<td>77.9</td>
</tr>
<tr>
<td>Nanning</td>
<td>72.3</td>
</tr>
<tr>
<td>Sanya</td>
<td>81.3</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>81.2</td>
</tr>
<tr>
<td>Shenyang</td>
<td>81</td>
</tr>
<tr>
<td>Shijiazhuang</td>
<td>75</td>
</tr>
</tbody>
</table>

### Table 5.8 Initial SLF for All Routes (continued)

<table>
<thead>
<tr>
<th>Route</th>
<th>Initial SLF/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taiyuan</td>
<td>83.5</td>
</tr>
<tr>
<td>Xian</td>
<td>83.8</td>
</tr>
<tr>
<td>Xiamen</td>
<td>74.7</td>
</tr>
<tr>
<td>Yinchuan</td>
<td>84.4</td>
</tr>
<tr>
<td>Zhangjiajie</td>
<td>82.2</td>
</tr>
<tr>
<td>Zhengzhou</td>
<td>78.1</td>
</tr>
<tr>
<td>Chongqing</td>
<td>86.8</td>
</tr>
</tbody>
</table>

The results for these two routes are shown in Figure 5.10 (Table A5.6 in Appendix A5). Airport revenues on these two routes grow when the airport charge increase does not exceed 40% over the baseline level, then reduce when the charge rate is increased by 60%.
Because of the lower SLF, the increase of the charge rate leads to passenger volume decreases, which means that the airlines will further reduce their flight volumes (because their SLF becomes lower than the set threshold). The reduced flight volumes is further affecting the airport revenues, through lower landing fees (because landing fee is charged on a per flight basis in NKG) and fewer passengers, which is translated into lower non-aeronautical revenues. Therefore, the SLF and SLF threshold are important factors in the airport decision to change the charge rate. Thus, the airports may consider charging different rates on the different routes/airlines depending on their SLF.

When low airfare levels (0.3 price-cap) are applied, more routes (eight routes) are shown with different changes on revenues brought to the airport (their revenues may decrease with the increase of the airport charge). The results of these routes are presented in Figures 5.11, 5.12, and Table A5.7 in Appendix A5.
As the charts suggest, at low levels of airfare (about 30% of the price-cap), the airport revenues are more sensitive to the charges. For some routes (Nanchang, Xiamen), increases above 20% the baseline airport charges lead to reductions in airport revenues; for others, with higher airfares (Shenyang, Xian, Dalian), airport revenues diminish only
when charge rates are above 60% the baseline level.

**Sensitivity analysis for all routes at Nanjing Airport**

Finally, sensitivity analysis was conducted with the simulated data at the route level. The results are shown in Table 5.9, where only the significant inputs to airport total revenues are retained (others, affected by multicollinearity, were not included). It appears that in relative terms, the activity of the airport, i.e. the number of flights (β=0.906) followed by the % change in the airport charges (β=0.356), are the most influential determinants of the airport revenues. The spending per pax in the terminal and the airfare values also play a significant role; the former is contributing to the non-aeronautical revenues, whereas the latter indicates that higher airfares can quickly absorb any increases in airport charges and cheaper airfares benefits the most from reductions in airport charges; yet, these factors are not as important as the number of flights and airport charges.

Table 5.9 Sensitivity Analysis Results (Nanjing Airport, Impact on Airport Revenue):

<table>
<thead>
<tr>
<th></th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-15.087 10E6</td>
<td>3.071 10E6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>SLF</td>
<td>98,409.55</td>
<td>34,996.015</td>
<td>0.005</td>
</tr>
<tr>
<td>Airfare (¥)</td>
<td>1,319,597</td>
<td>446,948</td>
<td>0.003</td>
</tr>
<tr>
<td>Charge rate % change</td>
<td>11.740 10E6</td>
<td>0.258 10E6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Number flights</td>
<td>6,377.174</td>
<td>53.189</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Demand elasticity</td>
<td>1.153 10E6</td>
<td>0.680 10E6</td>
<td>0.090</td>
</tr>
<tr>
<td>¥ spending per pax</td>
<td>0.501 10E6</td>
<td>72,959.555</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>¥ parking</td>
<td>66,786.046</td>
<td>49,263.258</td>
<td>0.175</td>
</tr>
</tbody>
</table>

Note: R² adj=0.925 (F-test = 2,419.01, p<0.001)

**Scenario 2 Airlines response to the change of the charge rate (airport and airline competitions excluded)**

In Scenario 1, the impact of the change of charge rate on the airport and airline revenues has been analysed for the case where charges are fully transferred to the passengers through the airfares. However, the airlines may decide to respond differently to changing
charge rates. This situation is investigated in Scenario 2, comparing the impact on the airport and airlines revenue, when airlines decide to keep their airfares unchanged, i.e. APP=0. The results are then compared to Scenario 1a in Tables A5.2 and A5.3, Appendix A5, where APP=1.

Firstly, the situation when the airport decreases the charge rate under both high and low airfare levels was simulated. The results are shown in Tables A5.8 and A5.9, Appendix A5. Because the number of passengers (10.605 million) and flights (85,082) remain constant, the tables present only the airport and airline revenues.

The comparisons (Table A5.8 with Table A5.2 and Table A5.9 with Table A5.3 in Appendix A5) reveal that both airport and airline revenues are slightly lower in Scenario 2. The differences between revenues are shown in Figure 5.13. The reason for this result is the constant number of travellers in Scenario 2 (unchanged airfares do not attract additional passengers) and the external conditions are assumed stationary. There is no clear “winner” in this scenario. When the airport charge rates decrease, under the high airfare level, the airlines are better off sharing this decrease with their passengers via airfares. Keeping the airfare unchanged makes some savings for the airlines, but they are modest compared to the benefits of additional passengers (provided that capacity reserves are present). Thus, passing on to passengers the decrease of airport charges will benefit both airlines and the airport (see Figure 5.13).

Not surprisingly, this effect is diminished under the low airfare level. It is also important to highlight that the airport revenues are the same in Scenario 2, independent of the level of the airfare (Table A5.8 and A5.9 in Appendix A5).
Next, the effect of an airport increasing the charge rate for both high and low airfare levels is tested. The results are shown in Figure 5.14 and Tables A5.10 and A5.11 in Appendix A5. As in the previous case, when increasing the airport charge, the airfare level does not affect the airport revenues, as the demand remains unaffected. However, the airline revenues vary substantially.

Figure 5.14 compares results from Table A5.10 with Table A5.4 and from Table A5.11 with Table A5.5 in Appendix A5, to highlight the effect of APP.
Figure 5.14 Nanjing Airport: Comparison between Revenues for Increases in Airport Charge (APP=0 vs APP=1)

Figure 5.14 indicates that when the airport increases its charge rate and the airlines do not pass these increases to their passengers through the airfares, both the airport and airlines gain more benefits. However, the increase in the airport charge will decrease proportionally the airline benefits. This further supports the findings in Chapter 4. To prevent airports from increasing their charges excessively, the aeronautical charge is regulated by the government and a price-cap is applied in China.
2) *Perth Airport*

As indicated in Chapter 4, the regulation regime in Perth Airport is light-handed, which means that the airport can decide its charge rate based on its costs and the market structure. Unlike Nanjing Airport, Perth Airport charges the airline-landing fee on a passenger basis. According to the published data on Perth Airport in 2011-2012, the landing rate for a domestic route is AUD 4 per arriving and departing passenger, the terminal rate is AUD 15 per arriving and departing passenger, and the security rate is AUD 3.6 per departing passenger (www.perthairport.com.au). Because Terminal 4 (domestic) is rented to and operated by Qantas; the airport does not charge any terminal fee nor any Passenger & Checked Bag Screening fee (included in security fee) to the Qantas domestic passengers through this terminal.

Two scenarios are applied to Perth airport – for five domestic routes with the highest traffic (Adelaide, Brisbane, Darwin, Melbourne, and Sydney) and for the top four airlines: Qantas (QF), Virgin (VA), Jetstar (JQ), and Tiger Air, in order to investigate the impact of uniform charged rate on the airport and how the airlines respond to the charge rate change. Several assumptions were made for these scenarios: i) the price elasticity of demand follows an N distribution with average -0.86 and standard derivation 0.1; ii) the charges are completely transferred to the passengers through the airfares; iii) the average spending amount used to derive the non-aeronautical revenues has a triangular distribution around AUD3.5 (range AUD3-5). These assumptions (Table 5.5) help to focus on the impact of the airport charges variation on the total airport revenue, without confounding effects from other inputs.

It is found that the total airport revenue is always positive to the change of airport charge rate. The following simulation shows the results for the low airfare level. The airfare and SLF applied in the simulation are provided in Table 5.10.
Table 5.10 Low Airfares and SLF of Five Domestic Routes and Four Airlines (Perth Airport)

<table>
<thead>
<tr>
<th>Airfare (AUD)</th>
<th>QF</th>
<th>JQ</th>
<th>VA</th>
<th>TIGER</th>
<th>SLF (%) by routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melbourne</td>
<td>247</td>
<td>220</td>
<td>237</td>
<td>123</td>
<td>75.8</td>
</tr>
<tr>
<td>Sydney</td>
<td>262</td>
<td>232</td>
<td>257</td>
<td>162</td>
<td>78.0</td>
</tr>
<tr>
<td>Brisbane</td>
<td>281</td>
<td></td>
<td>271</td>
<td></td>
<td>77.5</td>
</tr>
<tr>
<td>Adelaide</td>
<td>231</td>
<td>202</td>
<td>221</td>
<td></td>
<td>80.3</td>
</tr>
<tr>
<td>Darwin</td>
<td>281</td>
<td></td>
<td>337</td>
<td></td>
<td>66.9</td>
</tr>
</tbody>
</table>

**Scenario 1a Impact of the uniform airport charge rate on the airport revenue**

Because the regulation of Perth is light-handed, the range of simulation may be wider. The charge rate is set to vary between 80% decrease to 80% increase on the published charge rate. The results of these uniform charges are showed in Figure 5.15 and Table A5.12, Appendix A5.

![Figure 5.15 Perth Airport: Relationship between Changes in the Airport Charge Rate, Demand and Revenues](image)

Results indicate that the airport revenues decrease substantially with the reduction of airport charge rate, although lower charge rate brings more passengers to the airport. However, the airlines' revenues are increasing. Conversely, the increases in airport charges lifts up the airport revenues, but decreases the airline revenues. The changes are
dictated by the number of passengers which affects the aeronautical and non-aeronautical revenues differently, and the airline revenues as well. For the airport, reductions of airport charges leads to increased passenger volume and non-aeronautical revenues, which compensate (partially) for the loss in the aeronautical revenues. However, at Perth Airport, more passengers, attracted by lower airfares cannot bring enough revenue to compensate for the loss of aeronautical revenue. Therefore, it shows that airport revenue is positively changed with the change in the charge rate, while the association with airline revenue is negative. Overall, given the relative small proportion of the airport charges in the airfare, the changes in airline revenues are minimal (< 3%), whereas the changes for the airport are substantial (36-40%).

Scenario 1b Aeronautical Charge Rate Impact on Different Routes

When examining the results of applying Scenario 1a to different Perth domestic routes, the situation changes. Figure 5.16 (Table A5.13, Appendix A5) presents the airport and airline revenues for the route Perth-Darwin, which has the lowest SLF (66.7%).

A similar conclusion to that for the Nanjing airport is obtained: the airport revenues associated with the Darwin route will fall when the airport charge rate increases by 80%, whereas the airport revenues corresponding to the other four routes increase continuously with the increase of the charge rates (see Tables A5.12 and A5.13, Appendix A5). This is because airlines operating on routes with low seat loading factor need to make an additional decision, i.e. to reduce their number of flights when the low level of fleet utilisation makes the operation unsustainable. This finding points out that the airport decisions on charging rates should take into account the contextual situation and perhaps discriminate between airlines, based on the route demand, distances, the airline costs and their fares.
Similarly to the analysis for Nanjing Airport, the sensitivity analysis results (Table 5.11) show that the total airport revenue is positively related to the number of flights, changes in the airport charge rates and airfare levels. However, in the case of Perth Airport, the results are more sensitive to the changes in the airport charges ($\beta=1.142$), than to the traffic volume ($\beta=0.297$).

Table 5.11 Sensitivity Analysis Results (Perth Airport, Impact on Airport Revenue)

<table>
<thead>
<tr>
<th></th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Constant)</td>
<td>-43.265 × 10^6</td>
<td>8.403 × 10^6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Charge rate % change</td>
<td>5,636.751</td>
<td>310.935</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Airfare (AUD)</td>
<td>11.127 × 10^6</td>
<td>1.171 × 10^6</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Flights</td>
<td>0.129 × 10^6</td>
<td>0.027 × 10^6</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

Note: $R^2_{adj}=0.943$ (F-test = 243.08, p<0.001)

Overall, the sensitivity analysis emphasises that changes in the airport revenues depend on the scale of operation, the market conditions and the flexibility of the airport in adjusting its charges. This suggests that adopting a malleable policy of discriminating airport charges by route, airline and time would encourage operation for LCCs and routes.
with lower traffic, while still ensuring high revenues for the airport. Further analysis is carried out in Chapters 6 and 7.

Scenario 2 Airlines Response to the Change of Charge Rate (Airport and Airline Competitions Excluded)

Scenario 2 is then applied to Perth Airport to indicate the impact of not transferring the changes in airport charges to the passengers (APP=0). Figure 5.17 compares the airport and airline revenues for two situations: a) the airfares have a high level = 3*low airfares (results provided in Table A5.14, Appendix A5); and b) all airfares are at a low level (results provided in Table A5.15, Appendix A5). Similar to Scenario 1, the charge rate is modified in increments of 20%, between -80% to +80%. Again, the traffic volume is not affected by the changes in airport charge for APP=0.

The same implications, as in the case of NKG, were revealed for reductions in the airport charges. If the airfares are high, passing the reduction on to the passengers benefits both the airport and the airlines. When the airfares are low, airlines may prefer to keep the airfares unchanged, because the decrease in revenues is marginal (<1.5%). For the airport, a modification of the airport charge by 80% leads to a change in the revenues by 68-72%. The situation is different when the airport charges rise. Results indicate that at any airfare level, the airlines are better off if they pass the increase to their passengers via airfares. But this reaction to the increase of the airport charge rates would lower the airport revenues. Once more, the differentiated effect for airport and airlines is highlighted: whereas airline revenues modify by 2-3%, the airport revenues change by 65-70%.
The distinct findings between Perth and Nanjing airports may be explained by the different market power of these two airports and the magnitude of charges relative to airfares. Perth has higher market power and the ratio of airport charges over the average airfare is much lower than in NKG. Further exploration on how the different airlines respond to changes in such market conditions are discussed in Chapter 7.
CHAPTER 6 CASE STUDY IN NANJING AIRPORT

- COMPETITION WITH HIGH SPEED RAIL

In this chapter, the competition module has been developed according to the structure presented in Chapter 5. The level 2 model built in Chapter 5 has already been tested in the context of Nanjing airport, China and Perth Airport, Australia. In this chapter, the focus is on the effect of the competition between air transport and high-speed rail (HSR) on the airport and airlines revenues and how the airport and airlines work together to maintain their market share. A number of different scenarios are simulated and their results analysed, with the objective to find out how the airport and airlines could respond to the changes in the interurban travel market in order to increase their revenues. A further question is whether response of the airport affects the airlines and to what extent? This and the following chapter show how the level 2 System Dynamics Model built in Chapter 5 could be applied in different settings and circumstances to provide useful guidelines for airports and airlines when making revenue-related decisions.

6.1 Introduction of High Speed Rail (HSR) in China

6.1.1 Development of HSR in China

High-speed rail (HSR) in China refers to any railway with commercial train services at the speed of 200 km/h or higher, as internationally recognised. By this definition, China has the world's longest HSR network with over 16,000 km of track in service as of December 2014. The network is rapidly expanding and is expected to reach 18,000 km by the end of 2015, including 6,700 km of track capable of accommodating train speeds of 300–350 km/h and 11,300 km of track for train speeds of 200–250 km/h (Ollivier et
China's high-speed rail network consists of upgraded conventional railways, newly built high-speed passenger designated lines (PDLs), and the world's first high-speed commercial magnetic levitation (Maglev) line. Nearly all high-speed rail lines are operated by the government-owned corporation - China Railway High-Speed (CRH).

The network of HSR in China is showed in Figure 6.1 and the main routes are listed in Table 6.1 (Ollivier et al., 2014).
Table 6.1 Main HSR Routes in China (Ollivier et al., 2014).

<table>
<thead>
<tr>
<th>Line</th>
<th>Open Date</th>
<th>Length (km)</th>
<th>Speed (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Four North-South HSR Lines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Beijing-Shanghai line:</td>
<td>---</td>
<td>1,318</td>
<td>--</td>
</tr>
<tr>
<td>Beijing-Shanghai</td>
<td>June 2011</td>
<td>1,318</td>
<td>300</td>
</tr>
<tr>
<td>2. Beijing-Hong Kong line:</td>
<td>---</td>
<td>2,360</td>
<td>--</td>
</tr>
<tr>
<td>Beijing-Shijiazhuang</td>
<td>December 2012</td>
<td>281</td>
<td>350</td>
</tr>
<tr>
<td>Shijiazhuang-Wuhan</td>
<td>December 2012</td>
<td>841</td>
<td>350</td>
</tr>
<tr>
<td>Wuhan-Guangzhou</td>
<td>December 2009</td>
<td>1,069</td>
<td>300</td>
</tr>
<tr>
<td>Guangzhou-Shenzhen-Hong Kong</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guangzhou – Shenzhen:</td>
<td>December 2011</td>
<td>142</td>
<td>350</td>
</tr>
<tr>
<td>Guangzhou – Shenzhen – Kowloon 2015</td>
<td></td>
<td></td>
<td>200</td>
</tr>
<tr>
<td>3. Beijing-Harbin line:</td>
<td>---</td>
<td>1,700</td>
<td>--</td>
</tr>
<tr>
<td>Beijing-Shenyang</td>
<td>2014</td>
<td>709</td>
<td>350</td>
</tr>
<tr>
<td>Harbin-Dalian</td>
<td>December 2012</td>
<td>921</td>
<td>300</td>
</tr>
<tr>
<td>Panjin-Yingkou</td>
<td>September 2013</td>
<td>89</td>
<td>350</td>
</tr>
<tr>
<td>4. Hangzhou-Fuzhou-Shenzhen line:</td>
<td>---</td>
<td>1,450</td>
<td>--</td>
</tr>
<tr>
<td>Hangzhou-Ningbo</td>
<td>July 2013</td>
<td>150</td>
<td>350</td>
</tr>
<tr>
<td>Ningbo-Taizhou-Wenzhou</td>
<td>September 2009</td>
<td>268</td>
<td>200</td>
</tr>
<tr>
<td>Wenzhou-Fuzhou</td>
<td>June 2009</td>
<td>298</td>
<td>200</td>
</tr>
<tr>
<td>Fuzhou-Xiamen</td>
<td>April 2010</td>
<td>273</td>
<td>250</td>
</tr>
<tr>
<td>Xiamen-Shenzhen</td>
<td>December 2013</td>
<td>502</td>
<td>200</td>
</tr>
<tr>
<td><strong>Four East-West HSR Lines</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Xuzhou-Lanzhou line:</td>
<td>---</td>
<td>1,400</td>
<td>--</td>
</tr>
<tr>
<td>Zhengzhou-Xuzhou</td>
<td>2016</td>
<td>361</td>
<td>350</td>
</tr>
<tr>
<td>Zhengzhou-Xian</td>
<td>February 2010</td>
<td>505</td>
<td>300</td>
</tr>
<tr>
<td>Xian-Baoji</td>
<td>December 2013</td>
<td>138</td>
<td>250</td>
</tr>
<tr>
<td>Baoji-Lanzhou</td>
<td>2017</td>
<td>403</td>
<td>250</td>
</tr>
<tr>
<td>Line</td>
<td>Open Date</td>
<td>Length (km)</td>
<td>Speed (km/h)</td>
</tr>
<tr>
<td>------</td>
<td>-----------</td>
<td>-------------</td>
<td>--------------</td>
</tr>
<tr>
<td>2. Shanghai-Kunming line:</td>
<td>--</td>
<td>2,264</td>
<td>--</td>
</tr>
<tr>
<td>Shanghai-Hangzhou</td>
<td>October 2010</td>
<td>159</td>
<td>300</td>
</tr>
<tr>
<td>Hangzhou-Changsha</td>
<td>2014</td>
<td>927</td>
<td>350</td>
</tr>
<tr>
<td>Changsha-Kunming</td>
<td>2016</td>
<td>1,175</td>
<td>350</td>
</tr>
<tr>
<td>3. Qingdao-Taiyuan line:</td>
<td>--</td>
<td>770</td>
<td>--</td>
</tr>
<tr>
<td>Qingdao-Jinan</td>
<td>December 2008</td>
<td>362</td>
<td>250</td>
</tr>
<tr>
<td>Shijiazhuang-Taiyuan</td>
<td>April 2009</td>
<td>225</td>
<td>250</td>
</tr>
<tr>
<td>Shijiazhuang-Jinan</td>
<td>December 2015</td>
<td>319</td>
<td>250</td>
</tr>
<tr>
<td>4. Shanghai-Wuhan-Chengdu line:</td>
<td>--</td>
<td>2,078</td>
<td>--</td>
</tr>
<tr>
<td>Shanghai-Nanjing</td>
<td>July 2010</td>
<td>301</td>
<td>300</td>
</tr>
<tr>
<td>Hefei-Nanjing</td>
<td>April 2008</td>
<td>166</td>
<td>250</td>
</tr>
<tr>
<td>Hefei-Wuhan</td>
<td>April 2009</td>
<td>359</td>
<td>250</td>
</tr>
<tr>
<td>Wuhan-Yichang</td>
<td>July 2012</td>
<td>291</td>
<td>200</td>
</tr>
<tr>
<td>Yichang-Wanzhou</td>
<td>December 2010</td>
<td>377</td>
<td>160</td>
</tr>
<tr>
<td>Chongqing-Lichuan</td>
<td>December 2013</td>
<td>264</td>
<td>200</td>
</tr>
<tr>
<td>Suining-Chongqing</td>
<td>2012</td>
<td>131</td>
<td>200</td>
</tr>
<tr>
<td>Dazhou-Chengdu</td>
<td>July 2009</td>
<td>374</td>
<td>160</td>
</tr>
</tbody>
</table>

6.1.2 Comparisons of Performance and Costs

As indicated, over the past decade, China has undergone an HSR building boom with generous funding from the Chinese government’s economic stimulus program. The high-speed rail service, introduced on April 18, 2007, has shown an increasing traffic growing from 128 million to 672 million in 2013, with the daily ridership multiplying from 237,000 in 2007 to 2.49 million in 2014, which makes the Chinese high-speed rail network the most heavily used in the world. By October 2014, cumulative ridership has reached 2.9 billion (Ollivier et al., 2014; Bullock, et al., 2012).
At the end of 2013, the 27 HSRs in operation showed a unit cost of the 350 km/h projects between ¥ 94-183 million per km, while that of 250 km/h was between ¥70-169 million per km (Ollivier et al., 2014). China’s HSR service costs significantly less than similar systems in developed countries. In terms of fares, second class fares of HSR vary between ¥ 0.29 (US$0.045) per km at 200-250 km/h and ¥ 0.45 (US$0.077) per km at 250-350 km/h. This is about one fourth or one fifth of the HSR fares in other countries (e.g. France: 0.24-0.31 US$/km; Germany: 0.34 US$/km; Japan: 0.29-0.31 US$/km) (Ollivier et al., 2014). Although in China, HSR fares are three to four times more expensive than conventional unit train tickets, they are lower than average unit fares of full service airlines (¥ 0.7 per km).

Compared to other countries, China's HSR service also displays exceptional commercial speeds. For the 419 km trip from Beijing to Jinan, HSR takes 1:32 hours and costs CNY185 (US$30), while a conventional train costs CNY73 (US$12) and takes about 6 hours. By comparison, the Acela train from Washington DC to New York City, covering a slightly shorter distance of 370 km, takes almost three hours (2.50h) and costs US$152–180 (CNY930) (Fu et al., 2012). In Europe, the Eurostar train takes 2:15 hours for a 495 km trip and costs between US$61 and US$166 one-way ticket (http://www.seat61.com/London-to-Paris-by-train.htm#.VTHSRVxfP_8).

6.1.3 Impact of HSR on Chinese Airlines

The spread of HSR in China has forced domestic airlines to cut airfares and cancel regional flights. As the airline routes between 400 and 800 km represent about 30% of the total domestic airline network, they were heavily impacted by the introduction of HSR (Fu et al., 2012). By the end of 2014, commercial airline services had been completely halted on previously popular routes, such as Jinan - Qingdao (in 2008), Zhengzhou - Xian and Wuhan - Nanjing (in 2011). Around 50% of flights over distances of less than 310
km and about 20% of flights between 500 and 620 km became unprofitable in 2009 as a result of competition from HSR services (CAAC, 2010-2015; Albalate, et al., 2015). Flights on routes over 1,500 km remained generally unaffected (CAAC, 2010-2015; Fu et al., 2012). In 2013, 672 million domestic trips were made by the Chinese HSR services, twice the number of trips by air transport (327 million). While airline travel has grown at a rate of 13% per year between 2008 and 2013, HSR service growth has been substantially faster, at 39% (Bullock et al., 2012). In 2012, the average distance of a trip by air transport was 1,363 km. This distance continues to increase, as short-haul air routes (below 800 km) tend to be cancelled as a result of the HSR operation (Ollivier et al., 2014).

Bullock et al. (2012) and Givoni and Dobruszkes (2013) analysed traffic data from several HSR routes and found a substantial induced demand of HSR passengers on Wuhan-Guangzhou (968km) and Beijing-Tianjin (131km) routes. Including newly generated demand and mode transfer from car travel, the two routes increased their patronage by 45% and 80% respectively. Additionally, for Wuhan-Guangzhou, 5% of the demand for HSR was shifted from air transport.

6.2 Competition between Air Transport and HSR at Nanjing Airport

Currently, there are around 45 domestic routes operated by 20 airlines in NKG. Among all the linked cities, about 18 are also connected to Nanjing directly by HSR. The opening of HSR had a varying impact on the market share of air transport across these 18 routes. Based on the literature (see Chapter 2) and data analysis of the local data, it was found that travel time and distance are the most important factors determining the modal share in Nanjing. The longer the distance, the higher the preference for travelling by air. As with other international cases, air transport is seen as a dominant mode for long distance routes (above 800-1,000km), while there is competition with HSR on routes shorter than 1,000km and with travel time under five hours (Cascetta et al., 2011, 2013; Behrens and
To investigate the rail-air competition in NKG, seven routes were selected (HSR data is before June 2014; HSR on Nanjing-Nanchang that started from Dec 2014 is excluded).

Table 6.2 compares the characteristics of the seven routes and includes all the airlines operating on each route, before the HSR entered the market (route map see Figure A3.2 in Appendix A3).

### 6.3 Competition Model

This chapter elaborates on different scenarios for the *level 2* model at the airport-airline level, to explore the impact of the competition with HSR on airport revenues. This enables us to find out how the airport could provide a varying price scheme to the airlines, in order to arrive at “win-win” situations under different market structures.

#### Table 6.2 Comparison of Seven Routes Covered by Air and HSR at NKG (One-Way)

<table>
<thead>
<tr>
<th>Route (destination from NKG)</th>
<th>Flying distance (km)</th>
<th>Travel time a (hours)</th>
<th>Price b (¥)</th>
<th>Frequency c (per day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>HSR</td>
<td>Airfare</td>
<td>HSR (second class)</td>
<td>Air</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ticket (economy class range)</td>
<td>Airport tax + fuel tax</td>
<td></td>
</tr>
<tr>
<td>Beijing</td>
<td>981</td>
<td>1.8</td>
<td>4</td>
<td>182-1,010</td>
</tr>
<tr>
<td>Changsha</td>
<td>799</td>
<td>1.4</td>
<td>5.1</td>
<td>227-840</td>
</tr>
<tr>
<td>Qingdao</td>
<td>552</td>
<td>1.2</td>
<td>5</td>
<td>141-780</td>
</tr>
<tr>
<td>Tianjin</td>
<td>900</td>
<td>1.5</td>
<td>4.1</td>
<td>200-1,000</td>
</tr>
<tr>
<td>Wenzhou</td>
<td>655</td>
<td>1</td>
<td>4.5</td>
<td>135-710</td>
</tr>
<tr>
<td>Wuhan</td>
<td>504</td>
<td>1</td>
<td>3.5</td>
<td>146-730</td>
</tr>
<tr>
<td>Jinan</td>
<td>579</td>
<td>1</td>
<td>2.5</td>
<td>160-800</td>
</tr>
</tbody>
</table>

Note: The exchange rate in 2013 was in average 1AUD = ¥ 6.2; April 2015, 1AUD = ¥ 4.8; HSR data is by June 2014 and HSR on Nanjing-Nanchang started from Dec 2014 is excluded

a: Travel time: Only in-vehicle time (time spent during flight or when on HSR). The ground access time and the check-in time at the terminal are not included. Normally, at least one hour check-in time should be considered when travelling by air.

b: Price: the reference air price was obtained on 10/09/13. The airfares vary daily, while the HSR price was relatively fixed. In China, under the price cap, every airline could decide their effective/real price in different markets. In this
table, for the air ticket, the max value is the cap and the min value is the lowest price the airline changed on 10/09/13. Basically, the air price = ticket + airport charge and fuel tax.

c: Frequency: in the air transport, the frequency represents the number of total flights of all airlines flying on the same route. The frequency of the air transport was extracted from the schedule/timetable, before the HSR started operation.

The model described in Chapter 5 only focused on a “monopolistic market” of air transport. It was assumed that only one transport mode – air – could be chosen by the customers in all the routes. In many situations, airlines are facing the competition from other substitute modes (bus, car, train). As indicated in Section 6.1.1, NKG is operating in such an environment facing increasing competition from HSR. It is an ideal setting for this research on airport revenues, by which I can study the impact of competition between the air transport and HSR on airport revenues.

6.3.1 Purpose of the Model

This expanded competition model is built to identify ways in which the airport and airlines respond when facing the competition from HSR, and primarily what actions/decisions are beneficial to both sides. Based on the detailed level 2 model in Chapter 5, this competition level model could provide useful insights for airports with low market power on how to cooperate with airlines to ‘beat’ their common competitors.

6.3.2 Model Structure

The previous demand model (Section 5.2.1 and Figure 5.1) includes factors and relationships affecting airport demand without competition. In Figure 5.1, a blank module, named “Airport Competition” was included, with the objective to address the case of competition with HSR. In this module, the emphasis is on elements influencing the market share of air transport in a competition setting: the airfare and the presence of competition. In this model, the competition effect refers to the HSR advantages in relation to air transport. Thus, the airport competition module is designed to link the airfare change
and the HSR effect to the demand from the Demand module described in Section 5.2.1 (see Figure 5.1). Its structure reveals a range of characteristics determining the airport demand in a competitive market. After examining 16 routes, both covered by air and HSR in China, to and from Nanjing Airport, four factors appeared as the main drivers of air market share/passenger demand: i) travel time; ii) price; iii) price elasticity of demand; and iv) frequency of services. They will be discussed in detail in the following.

(i) Travel time

HSR has demonstrated its advantage in the short-haul routes <800-1,000km (Givoni 2006; Givoni and Dobruszkes, 2013). In the level 2 model, travel time was used to describe the most important element in the decision making process, especially for time sensitive passengers. In the competition model, the reference travel time is the travel time by HSR, because the travel time difference between HSR and air transport (including access time, check-in and security time) is not distinct among the selected routes included in the model. HSR can compete with air transport on routes shorter than 1,000km and with travel time less than 5 hours (Steer Davies Gleave, 2006; Givoni and Dobruszkes, 2013), therefore, a graphic function (variable named travel time factor in Figure 6.2) is set here to explain the impact of travel time on the demand of air transport, as a function between HSR travelling time and % change in air transport/airport demand (see Table 6.3). This is a sketch of a relationship between an input (which itself can be an algebraic relationship) and an output (Sterman, 2000).

(ii) Price

Price is considered an essential factor for the market share, especially given the substantial modal differences in fares. The price is related to the operation cost. Based on data from China in 2011, average HSR fares were calculated at ¥ 0.48/km for lines at
speed 350km/hr and ¥ 0.3/km for lines at speed around 250 km/hr. In contrast, airfares typically have an average of ¥0.70/km (average economy fare for full service airlines) (Bullock et al., 2012; Givoni and Dobruszkes, 2013).

Again, for simplicity, the model designed here does not classify passengers into different classes (first, business, economy), but it rather considers an average price level. Because Economy Class for air and Second Class for HSR train are the dominant segments, their prices are compared in the model and denoted as the generic airfare and HSR prices (Figure 6.2). In China, HSR route is only operated by one government-owned company, while an air route could be operated by different airlines. That means that various airlines operating on the same route could change their airfare under the price cap, while the HSR fare is relatively fixed.

(iii) **Price elasticity**

Any change in airfares or in the HSR tickets prices will be reflected in changes in the passenger demand for air travel through the price elasticities. In this competition model, the price elasticity includes two components: own price elasticity (airfare) and cross elasticity (HSR). The own-price elasticity of demand measures the responsiveness, or sensitivity, of the demand for a good to changes in its price when other influences on demand are held constant. It may be approximated by the percentage (%) change in quantity demanded resulting from a given percentage (%) change in price (Table 4.1 Section 4.2)

---

8 The fare is considered as average value for all routes, calculated by dividing published HSR second-class fare by distance (because HSR ticket price is fixed without any discount in China). In fact, unit fare is more expensive for shorter trips based on the construction cost.
In this chapter, the value of price elasticity for these seven selected routes (504-981km) ranges from -1.25 to -1.57 ⁹ (IATA, 2007).

Cross-price elasticity, on the other hand, is the percentage (%) change in quantity demand for, let us say, air transport, in response to a percentage (%) change in the price of another service, such as HSR. For substitutable goods, the cross-price elasticity is positive, while it is negative for complementary goods. If two products are unrelated to one another, the cross-price elasticity of demand would be zero (Cole, 2005; Oum et al., 2000). A note is important at this stage: because in China there is no change in the prices of the HSR tickets, the impact of the HSR cross-elasticity is excluded here.

(iv) Frequency

Frequency is another important factor in modal choice for intercity travel. For example, for routes with similar travel time, the mode or airline market share varies because of the varying frequency. The elasticities of demand with respect to frequency are expected to have the opposite sign to price: if the frequency increases in favour of one transport mode, a demand increase is expected for that mode, everything else kept constant. However, changing frequencies is subject to capacity constraints. The frequency of services offered by airlines is restricted by the total capacity of the airport and by the market share in earlier years, due to ‘grandfathering’ of slots. The frequency of services for HSR is limited by the capacity of railway stations, signaling system, or by rolling stock. Because currently HSR has substantial reserves of capacity, the issue is relevant only for the airport and airlines.

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⁹ Based on IATA (2007), this value = base multiplier for route level (-1.2 to -1.5) * Geographic Aviation Market multiplier for Asia (0.95)*Short-haul adjustor (1.1)
Typically, an improvement in the frequency of services from every 2 hours to every 1 hour is equivalent to a reduction in travel time of 20-30 minutes (Steer Davies Gleave, 2006). Frequency factor is the impact on demand of air transport of the difference in daily frequency of HSR and air travel services. It is an adjustor of travel time factor to determine HSR factor (Figure 6.2), which is % change in demand of air transport affected by HSR travel time and frequency. The calculation is shown in relations 6-1 to 6-3 and Table 6.3 (Steer Davies Gleave, 2006).

\[
\text{HSR factor} = \text{Travel time factor} \times \text{Frequency factor}
\]

\[
\text{Frequency factor} = f (\text{Frequency difference})
\]

\[
= \begin{cases}
1.5 & \text{if Frequency difference} \geq 5 \\
1 & \text{if } 1 \leq \text{Frequency difference} < 5 \\
0.8 & \text{if Frequency difference} < 1
\end{cases}
\]

\[
\text{Frequency difference} = \frac{\text{HSR frequency}}{\sum \text{Airline frequency}}
\]

Figure 6.2 highlights the main structural differences of the competition model compared to Figure 5.1.
As already indicated, under the competition conditions, the airport demand is changed by two factors: the influences of airfare and the HSR (components in red in Figure 6.2). On the one hand, the change of the airfare has an impact on the demand through the price elasticity of demand. In the NKG case, it is assumed that an airline may change its airfare in two situations – to match the price of HSR or if the airport charges are modified. On the other hand, time and frequency may increase demand for the airlines that offer a wider range of services. In order to simulate the effect of changing travel time and frequency on the market share of HSR (illustrated as the HSR effect), two new parameters are introduced. Two graphic functions are employed to describe the relationships between travel time and frequency and the number of passengers (the demand). Therefore, when the HSR enters the market and starts operation, this will affect the airport demand through the HSR elasticity, as a function of different HSR travel times and frequencies on a route. Accordingly, the airlines and the airport are expected to respond to these variations in the market.

As the objective of the competition model is to identify what actions are beneficial for both airlines and airports when a new modal competitor offers attractive services in that market, additional inputs are required. Table 6.3 presents the main types of inputs used in the competition model.

Table 6.3 Inputs in the Competition Model

<table>
<thead>
<tr>
<th>Type</th>
<th>Input</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR</td>
<td>HSR entering time</td>
<td>When HSR enters the market for a specific route.</td>
</tr>
<tr>
<td></td>
<td>HSR initial price</td>
<td>The HSR price when entering the market.</td>
</tr>
<tr>
<td>Demand change</td>
<td>Price elasticity of demand</td>
<td>Defined in Table 4.1. Value ranges from -1.25 to -1.57.</td>
</tr>
<tr>
<td></td>
<td>Travel time factor</td>
<td>A graphic function between HSR travelling time and % change in air transport/airport demand, ( y = % \text{ change in demand of air transport} = f (\text{HSR travel time}) ), which is based on the</td>
</tr>
<tr>
<td>Type</td>
<td>Input</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>relationship between HSR travel</td>
<td></td>
<td>time and its market share (Steer Davies Gleave, 2006).</td>
</tr>
<tr>
<td>Frequency difference between</td>
<td>HSR frequency/∑Airline</td>
<td>frequency.</td>
</tr>
<tr>
<td>HSR and airlines</td>
<td>frequency.</td>
<td></td>
</tr>
<tr>
<td>Airline response</td>
<td>Airfare change %</td>
<td>The proportional change of the airfare in response to the HSR competition.</td>
</tr>
<tr>
<td>Airline response time</td>
<td></td>
<td>When the airlines change their airfares as a result of the competition with HSR.</td>
</tr>
<tr>
<td>Airline frequency policy (in the</td>
<td>Dummy variable indicating if</td>
<td>airlines change the number of the flights in response to the competition if takes the values: 1 = frequency can be changed under the conditions set in the model; 0 = frequency of the airline cannot be changed.</td>
</tr>
<tr>
<td>Traffic Module, Figure 5.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airline aircraft policy (in the</td>
<td>If airlines decide to change</td>
<td>The type of the aircraft, adjusting to the demand level. Dummy variable taking the values: 1 = aircraft type could be changed under the conditions set in the model; 0 = aircraft type of the airline cannot be changed.</td>
</tr>
<tr>
<td>Traffic Module, Figure 5.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airport response (see Figure 5.4</td>
<td>Change in Airport charge</td>
<td>The proportion change of the airport charge. The charge includes three components: landing, terminal and security.</td>
</tr>
<tr>
<td>in the Airport Aeronautical</td>
<td>Time for changing the airport</td>
<td>Timing when the airport decides to change its charges.</td>
</tr>
<tr>
<td>Revenue Module)</td>
<td>charge</td>
<td></td>
</tr>
<tr>
<td>Airport-airline agreement</td>
<td>The change of discount in the</td>
<td>The airport charge applied to an airline, under a specific agreement.</td>
</tr>
<tr>
<td>Effect time</td>
<td>Time when the agreement</td>
<td>applies effectively.</td>
</tr>
</tbody>
</table>

![Travel Time Factor](image_url)
6.4 Model Validation

In the case of the NKG airport, most HSR routes started operation in June 2011. To test the validity of the model, the actual annual numbers of passengers before and after HSR entered the market were compared with the model results.

Table 6.4 indicates a substantial impact on the air traffic as a result of HSR operation, with flights stopping on four routes and decreases of passengers up to 94%.

Table 6.4 Traffic Statistics for Seven Main Air Route from/to Nanjing (Two-Way Traffic)

<table>
<thead>
<tr>
<th>Route/Nanjing to and from</th>
<th>The annual pax before HSR/Year 2010</th>
<th>The annual pax after HSR/Year 2012</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>1,755,650</td>
<td>1,047,095</td>
<td>-40%</td>
</tr>
<tr>
<td>Changsha</td>
<td>685,571</td>
<td>415,447</td>
<td>-39%</td>
</tr>
<tr>
<td>Qingdao</td>
<td>347,593</td>
<td>275,416</td>
<td>-20%</td>
</tr>
<tr>
<td>Tianjin</td>
<td>265,474</td>
<td>46,820 and stop operation</td>
<td>-82%</td>
</tr>
<tr>
<td>Wenzhou</td>
<td>72,514</td>
<td>Data not available / stop operation</td>
<td></td>
</tr>
<tr>
<td>Wuhan</td>
<td>174,163</td>
<td>9,979 and stop operation</td>
<td>-94%</td>
</tr>
<tr>
<td>Jinan</td>
<td>106,990</td>
<td>Data not available / stop operation</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.5 shows the modelled impact of HSR and the airlines’ response on the market. In this case, a reduction of the airfares by 20% was considered when the HSR entered the market, consistent with the actual measures applied in NKG airport. The simulation compared the change of the annual passengers in two cases: without HSR and with HSR based on the data in 2011, when the HSR entered the market.

Table 6.5 Simulation Results for Seven Air Routes from/to Nanjing

<table>
<thead>
<tr>
<th>Route</th>
<th>The annual pax without HSR</th>
<th>The annual pax with HSR</th>
<th>Change (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beijing</td>
<td>1,636,438</td>
<td>955,262</td>
<td>-42%</td>
</tr>
<tr>
<td>Changsha</td>
<td>647,212</td>
<td>397,090</td>
<td>-39%</td>
</tr>
<tr>
<td>Qingdao</td>
<td>319,464</td>
<td>258,121</td>
<td>-19%</td>
</tr>
<tr>
<td>Tianjin</td>
<td>292,855</td>
<td>56,261</td>
<td>-81%</td>
</tr>
<tr>
<td>Wenzhou</td>
<td>87,786</td>
<td>9,323</td>
<td>-89%</td>
</tr>
<tr>
<td>Wuhan</td>
<td>181,694</td>
<td>14,230</td>
<td>-92%</td>
</tr>
<tr>
<td>Jinan</td>
<td>140,198</td>
<td>9,637</td>
<td>-93%</td>
</tr>
</tbody>
</table>
Tables 6.4 and 6.5 indicate similar relative changes with errors lower than 5%, which gives confidence in the model results. Although the simulation results are slightly lower than the statistics, their values present different years’ data and thus are not directly comparable.

6.5 Scenario Setting

A number of scenarios were simulated to test the effects of changes in different parameters. They reflect combinations of airline and airport decisions and include:

Scenario 1 - *The impact on airport and airline global revenues of the time taken by the airlines to respond to HSR entering the market.*

Scenario 2 - *The impact of the different airfares applied by airlines on the airport revenues (frequency and aircraft type unchanged).*

Scenario 3 - *The impact of a change in airline frequency on airport revenues.*

Scenario 4 - *The impact of a change in airport charges on revenues of airlines.*

It is important to note that, in this chapter and hereafter, the total airline revenues only refer to the remaining revenues after deducting the total airport fees paid to the airport from the tickets sale\(^ {10} \).

In all scenarios, the base case is the situation when airports and airlines do not face competition with HSR, assuming that the initial airfare is set at 70% of the price cap, on each route, for all the airlines. First, these scenarios are used to examine the impact on

\(^{10}\) I remind the reader that, in this thesis, the total airline revenue is considered after deducting airport charge form airline tickets sale and other corresponding costs incurred by the airlines, such as fuel consumption, maintenance of the aircrafts are not considered in the model.
the global revenues of the airport and of the airlines, then an investigation of the effects at the level of individual airlines is undertaken.

6.5.1 Impact at the Global Level

Scenario 1 Impact on airport and airline global revenues of the time taken by the airlines to respond to HSR entering the market.

This scenario relies on the assumption that all airlines reduce airfares by 20% to compete with the HSR, without change in the airline frequency. However, the time when the airlines take this action would have varying influence on the market. Thus a comparison of the different interactions of airlines responding to the HSR is warranted in order to find out how their revenues are affected. The results of the simulation are given in Figure 6.3 and Table A6.1 in Appendix A6.

Figure 6.3 suggests that the response time of the airlines has a great influence on the revenue of the airport and the airlines. The results indicate that airlines’ early action, by reducing the airfare, is beneficial both for the airport (revenue ¥122.8 million compared with ¥100 million after) and the airlines (revenue ¥38,520/flight compared with ¥31,106/flight after), as more passengers (2.3 million compared with 1.8 million after) are attracted by lower airfares (Case 3 and 5 in Figure 6.3). However, the presence of HSR has substantial negative impact on the airport passengers and airport and airlines’ revenues. Such impact is greater on the airline revenues than on the airport. If the number of flights remained at the same level (26,280), the revenue per flight substantially diminished.
In this scenario, all the airlines are assumed to reduce their airfares in the same proportion to reduce the gap between airfare and HSR price.

Scenario 1 already highlighted that the airline response time is an important factor for maintaining revenues. Thus scenario 2 considers the impacts of the airfare change, both before and after HSR entering the regional travel market, on the total airport revenues and the total airline revenues. The results of the simulation are presented in Figure 6.4 and Tables A6.2 and A6.3 in Appendix A6.
The results confirm once more that the opening of HSR has a significant impact on the market for air transport, leading to the considerable decrease in the passengers travelling by air (from 3.3 million to 1.5 million). However, by decreasing the airfares, especially before HSR entry, airlines may re-capture an increasing number of passengers. Being “pro-active” and anticipating the effects of the HSR competition has benefits for airlines and consequently for the airport. The revenues of the airport will increase when airfares are cut back (no matter when the airlines reduce their airfares), as the airport revenues are positively related to the number of passengers. However, if airfares decrease after HSR entry, airport revenues drop even with a reduction in airfares, compared to the revenues when HSR was not in operation.
As stated in Scenario 1, the airline response time has an obvious impact on the revenue of the airlines. The total revenue of airlines is much higher if the fare changes occur before the HSR enters the market. If the airline market is “reactive”, changing airfare after HSR starts operation, there are different revenue effects for airport and airlines: whereas if the airport revenues increase in proportion to the increase in the number of passengers resulting from a more attractive airfare, the airlines experience losses from their reduced airfares.

On the other hand, if the airlines reduce the airfare in advance of the HSR entering the market (Table A6.2 in Appendix A6), some of their losses could be recovered by the higher number of passengers. Therefore, under unchanged frequency and aircraft size, the results indicate that airlines should consider reducing their airfares in advance of the HSR entering the market, in order to maintain the market share and/or to attract more passengers. Otherwise, if HSR has already entered the market, without holding their higher airfares and the advantage of some service features, their revenues and profits would be substantially cut.

Scenario 3 Impact of Change in Frequency of Services

The above scenarios 1 and 2 assume business-as-usual in terms of operation, i.e. the same frequency of flights. Considering that the reduction in passengers directly affects the load factor, it is expected that airlines would change the frequency and aircraft sizes, in response to the competition. This scenario explores changes in revenue if the airlines change their frequency of flights. This is done again in two situations: airlines react before and after HSR entering the market. The results are presented in Figures 6.5 and 6.6 and Tables A6.4 and A6.5 in Appendix A6.
From the results, it has become apparent that changing frequency has a significant effect on both airlines and airports. Reducing frequency is an effective action for airlines to diminish costs and for airport to cope with capacity constraints, but at the same time it is
negatively affecting the airport revenues. When the demand decreases, the airlines are likely to reduce their frequency to get the higher load factor, which is very important for covering their costs and achieving a break-even situation. If the airlines are interested in raising their revenues per flight, adjusting frequency seems a good strategy. However, lower frequency may lead to fewer passengers in the longer-term, especially those passengers responsive to time, which now will have lower flexibility for travel. These passengers may transfer to other airlines with a wider set of flight options, or to HSR, which runs every hour.

As shown in this case, to suit their financial interests, airlines are incentivised to adopt higher airfares and lower frequency (case 3); which increases revenues per flight or unit profit for airlines, but has an opposite effect on the airport revenues - airport revenues decrease with the lower frequency. The airport and the airlines may be seen as standing at the two different positions, with different interests. To reach a “win-win” situation, both parties should work together and compromise, to attain a commonly beneficial solution. When comparing all cases (case 2 to 5), case 5 when airline decreases airfare by 20% and adjusts flight frequency seems a satisfying choice for both airlines and the airport, with higher revenues. In this case, the airport may motivate the airline to decrease its airfare by decreasing airport charge rate in order to prevent the airline from substantially decreasing its frequency.

Both airlines and the airport reduce their revenues if they are “reactive” (rather than “pro-active”) and apply their selected measures after the HSR starts its operation. As also shown in Scenario 2, airlines would benefit from anticipating the market changes and acting early on them.
Scenario 4 Impact of a change in airport charges

Previous analysis presented in Scenarios 1-3 simulated how airlines respond to the presence of a competitor (HSR), however, it is known that there are some common interests for the airport and airlines to address the ‘potential market threat’ posed by the HSR. In this situation, the airport also needs to take actions to avoid losing its customers and profit. One possibility is to reduce the airport charges. Figures 6.7 and 6.8 compare the results from different situations when the airport reduces their charges. At each airfare level, the situation when the airlines pass the decrease of airport charge onto the passengers is compared to the option of keeping it. The numerical results of the simulation are provided in Tables A6.6 and A6.7 in Appendix A6.
The two diagrams further emphasise the importance of airlines moving ahead of their competitors, based on the market directions. At the same airfare values and for the same percentage reduction in airport charge, the number of passengers and the airport and airline revenues are much lower if the airlines react to the market moves after HSR starts its operation (the shape of the radar diagrams changes). For example, for an airfare reduced by 50% and airport charge by 40%, the number of passengers falls from 2.5 million to 1.9 million and the airport revenues from ¥93 million to ¥72 million, when the airlines change their policies only after HSR started their operation. The airline revenues decrease as well, in the same direction, however they remain slightly higher if the reduction of airport charge is not included in the airfare (e.g., ¥3 million difference when the changes in airport charges occur before the HSR enters the market and 38 million
difference when the changes are made after the HSR entered the market). As expected, the lowest frequencies are associated with the lowest level of overall revenues and, conversely, with the highest revenues/flight.

In addition, there is a trade-off between revenues and market share (expressed as number of passengers). Irrespective of when the airlines decide to decrease their airfares, there is a lower bound/threshold, below which they cannot reduce their airfares (e.g. at 30% of the standard/capped airfare, the revenue per flight varies between 32 and ¥35,000, see Cases 8-10). At this level, even the reduction of 40% in the airport charge is of little help in recouping the costs.

Finally, Figures 6.7 and 6.8 both show that, at the same airfare level, the airport revenues decrease after the airport reduces charges, while the revenues of airlines increase. As indicated, if the airlines take action before HSR enters the market, they should reduce their average airfare by a reasonable amount (e.g. -20% compared to 0.7*price cap, as in cases 5 to 7 in Figure 6.7 and Table A6.6 in Appendix A6) which will get them higher revenues compared with “doing nothing” (cases 2 to 4 in Figure 6.7 and Table A6.6 in Appendix A6). In this situation, the airport would be better off to keep their charge rate unchanged and benefitting from the airfare reductions. On the other hand, if the airlines take actions after HSR entering the market, the airport is the main beneficiary of the airfare reduction. In terms of airline revenues, the airlines would prefer higher airfares, but if they are not flexible enough in applying their fare policies, this would result in losses of market share. High airline fares, in the presence of HSR, will lead to substantial revenue deficits for the airport too (see case 2 in Figure 6.8 and Table A6.7 in Appendix A6). When comparing only scenarios of changes after HSR entered the market (cases 2 to 7 in Figure 6.8 and Table A6.7 in Appendix A6), it appears that reduction of airfare and airport charge, passed on to the passengers (case 6) is the best solution for the airlines and the second best for the airport. However, if the airport does not reduce the charge, the
airlines are encouraged to reduce the frequency of their flights as a measure to increase or maintain revenues (case 2 in Figure 6.8 and Table A6.7 in Appendix A6). This may have a detrimental effect on the airport revenues. Therefore, it appears to be a natural solution to have some negotiation between the airport and the airlines, pre-emptying the major market changes, in order to reach a least-loss situation for both.

These scenarios suggest that continuing airport charge reductions, adjusting frequency and airfare may be the best combination for achieving highest revenues. The same conclusion was reached in the situation where there is no external travel mode competing against air travel (Chapter 5): if the airport decreases the charge rate, the airline benefits from passing the reduction on to the passengers directly, through the airfares, because lower airfares attract more passengers.

6.5.2 Impact at the Route Level

In this section, the impact of changes in the airfares is presented on a route basis. Up to now, the differences among the airlines have been ignored, assuming that all airlines have similar airfares on a particular route and that they take similar actions in response to external market conditions. Results from Section 6.5.1 have led to the conclusion that airlines are likely to reduce their flight frequency as a response to the modal shift associated with the competition from HSR. But this decision needs to be fully informed, as the flexibility of services is affected. Also, airlines are more likely to apply their own fare discounts, not necessarily the same amount as other airlines.

Consequently, this section will analyse the effect on the number of passengers and revenues if airlines change airfares and frequencies before and after HSR entering the market. The base case still remains the situation when HSR does not operate and the
initial airfare is 70% of the price cap on each route for all the airlines. The HSR fares and different airfares applied in the following simulations are presented in Table 6.6:

Table 6.6 Airfares and HSR Fares Used in Simulation (¥)

<table>
<thead>
<tr>
<th>Ticket price</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR price</td>
<td>444</td>
<td>333</td>
<td>400</td>
<td>400</td>
<td>270</td>
<td>167</td>
<td>279</td>
</tr>
<tr>
<td>Full airfare</td>
<td>1,010</td>
<td>840</td>
<td>780</td>
<td>1,000</td>
<td>710</td>
<td>810</td>
<td>800</td>
</tr>
<tr>
<td>Airfare = 0.7*full price</td>
<td>707</td>
<td>588</td>
<td>546</td>
<td>700</td>
<td>497</td>
<td>567</td>
<td>560</td>
</tr>
<tr>
<td>Airfare = 0.5*full price</td>
<td>505</td>
<td>420</td>
<td>390</td>
<td>500</td>
<td>355</td>
<td>405</td>
<td>400</td>
</tr>
<tr>
<td>Airfare = 0.4*full price</td>
<td>404</td>
<td>336</td>
<td>312</td>
<td>400</td>
<td>284</td>
<td>324</td>
<td>320</td>
</tr>
<tr>
<td>Airfare = 0.3*full price</td>
<td>303</td>
<td>252</td>
<td>234</td>
<td>300</td>
<td>213</td>
<td>243</td>
<td>240</td>
</tr>
</tbody>
</table>

Scenario 1 Airlines respond after HSR enters the market

In Nanjing, HSR operation has posed a new challenge for all the airlines because of the limited experience with this new type of competition. An analysis of the operation data shows that in NKG, most of the airlines changed their airfares and frequencies only after the HSR entered the market, with very few taking some actions in advance (e.g. providing more convenient services, to reduce the waiting time in the terminal, was initiated by East China Airline).

In this scenario, the impact on different routes is assessed, when airlines reduced the airfares and adjusted frequency after the HSR started operation. The description of the cases analysed in this section is provided below.

Case 1 - baseline, without HSR, price = 0.7*price cap
Case 2 - with HSR, price = 0.7* price cap, no action for airlines
Case 3 - with HSR, price = 0.7* price cap, change frequency
Case 4 - with HSR, price = 0.5* price cap, change frequency
Case 5 - with HSR, price = 0.4* price cap, change frequency
Case 6 - with HSR, price = 0.3* price cap, change frequency
Given the level of detail (seven routes), the impact of any airport and airline measures is presented separately by number of passengers, flights, and the revenues for airport and airlines. Figures 6.9 to 6.12 compare the absolute values for the indicators by route, and Tables A6.8 to A6.11 in Appendix A6 provide the supporting data, along with the relative change compared to the baseline (case 1).

Figure 6.9 Impact on Number of Passengers by Route of Airline Response after HSR Entry

Figure 6.10 Impact on Number of Flights by Route of Airline Response after HSR Entry
The results show that after the HSR started operation on various routes, there were differentiated effects by origin-destination relationships. Dramatic decreases of the number of passengers were experienced on three routes: Wenzhou, Wuhan and Jinan (more than 70%)\textsuperscript{11}. Consequently, the airport and the airline revenues fell substantially

\textsuperscript{11}Wenzhou, Wuhan, and Jinan are presented first for each case in Figure 6.9-6.12.
on these routes (Figures 6.11 and 6.12). Even when the airlines reduced their airfares to match the HSR, they could not improve their market situation and preserve their financial revenues. Therefore, the airlines flying these routes had to terminate their services in response to the competing HSR operation.

For Tianjin destination, if airlines reduce the airfare to match the HSR ticket price, they will still lose almost half of the market and more than 70% of their revenues. Additionally, although both the airlines and the airport intend to charge lower airfares and airport fees, it is difficult to break the ¥ 400 barrier (the HSR price), because the average cost of airlines for this route is higher, around ¥ 450/passenger (the average cost per available airline seat*kilometer in China was about ¥ 0.50 in 2012 (CAAC, 2010-2015).

The situation is distinct for the Beijing, Changsha, and Qingdao routes, where the airlines could reduce their airfares to prevent passengers from transferring to HSR. However, lower airfares will erode the airline revenues. Considering the revenue per flight (airline revenues / number of flights, in Table A6.8- A6.11 in Appendix A6) and the passenger volume, it appears that case 4 (0.5* price cap with adjusted frequency) may a better solution for these routes. The % changes in airline revenue per flight and number of passengers are compared in Table 6.7.

Table 6.7 Impact on Airline Revenues per Flight and Number of Passengers by Route after HSR Entry

<table>
<thead>
<tr>
<th></th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airline</td>
<td>Number</td>
<td>Airline</td>
</tr>
<tr>
<td></td>
<td>revenues/flight</td>
<td>of pax</td>
<td>revenues/flight</td>
</tr>
<tr>
<td>Case 1</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Case 2</td>
<td>-50%</td>
<td>-49%</td>
<td>-62%</td>
</tr>
<tr>
<td>Case 3</td>
<td>-13%</td>
<td>-57%</td>
<td>-13%</td>
</tr>
<tr>
<td>Case 4</td>
<td>-33%</td>
<td>-42%</td>
<td>-27%</td>
</tr>
<tr>
<td>Case 5</td>
<td>-45%</td>
<td>-38%</td>
<td>-47%</td>
</tr>
<tr>
<td>Case 6</td>
<td>-58%</td>
<td>-34%</td>
<td>-59%</td>
</tr>
</tbody>
</table>

* Compared to the case 1- without HSR
In this case, when airlines decreased airfare by 20% and frequency (case 4) the passenger volume dropped by only 19% at Qingdao route (compared to 37% when the airfare is unchanged), with Beijing experiencing decreases by 42% and Changsha by 39%. The different impact is due to the higher HSR ticket price on the Qingdao route, compared to other similar routes in distance and the competitive airfare. Because on the Beijing, Changsha and Qingdao routes the airport also benefits from the lower airfares, lower airport charges are a sensible solution for the airport, to enable airlines to reduce their airfares.

Related to this, Case 3 of changing frequency, but maintaining the airfares at 0.7 price cap, is associated with the least reduction of revenues and flights, but the largest reduction in demand.

Finally, a similar pattern of variation is noticed for flights, although, on routes with higher demand the changes are less dramatic than on lower traffic routes, which have greater difficulty in adjusting to the new market conditions. Considering the proportionality between number of passengers and airport revenues, the quick impact of HSR presence on the airfare reduction with the decrease in frequency is most obvious on the Tianjin, Wenzhou, Wuhan and Jinan routes; because of the combination of shorter travel time, higher frequency of the HSR services and lower HSR fares. As a result all the airlines are likely to eventually quit those routes because of the pressure from the HSR.

**Scenario 2 Airlines respond before HSR enters the market**

The analysis of the impact at global level (in Section 6.5.1) suggested that earlier action taken by airlines would benefit both airlines and airports. This section analyses the different impacts on the different routes. Figures 6.13 to 6.16 (Tables A6.12 to A6.15, Appendix A6) present the results of the analysis in the situation when the airlines reduce
their airfares and frequencies of flights before the HSR starts operation on the routes. The following cases are compared:

Case 1 – baseline, without HSR, price = 0.7*price cap
Case 2 – with HSR, price = 0.5*price cap, frequency changed
Case 3 – with HSR, price = 0.4*price cap, frequency changed
Case 4 - with HSR, price = 0.3*price cap, frequency changed

Figure 6.13 Impact on Number of Passengers by Route of Airline Actions before HSR Entry

Figure 6.14 Impact on Number of Flights by Route of Airline Actions before HSR Entry
Acknowledging that keeping high airfares without changing their service is not a feasible option for airlines if they want to remain competitive, two cases (corresponding to “no action”, and only changing frequency of flights but not the airfares) were not included in this scenario.
All the results show that, except for Wuhan and Jinan routes (the first two in all charts), if the airlines respond appropriately before HSR enters the market (match or offer airfares below the HSR price and adjust their frequencies), they could avoid significant losses. Conversely, for Wuhan and Jinan, regardless of the actions taken by the airlines, their revenues (and the airport’s) will be cut. On these routes, the airlines inevitably will lose their passengers, suggesting that quitting the service may be a more viable alternative. For these two routes with the short travel time by HSR (less than 4 hours), airlines cannot ‘beat’ the rail competitor, because of the high frequency (more than twice as much as airlines) and low price (equal to or less than 30% of the full airfare) of HSR. This means that the airlines need to reassess the feasibility of their operation on those routes, or address a different market segment with different services.

Based on all the results presented in Scenarios 1 and 2, it can be concluded that the airlines will experience losses on the Wuhan and Jinan routes, with a practical option being to stop these services. What is more, the decision of the airlines to quit would also benefit the airport, because inefficient operation lowers the airport revenue as well. So in this case, the airport would prefer to assign these newly available slots to other profitable routes.

For the Tianjin route, if the airlines could respond before HSR enters the market and beat its price, there is still a possibility for airlines to fly on this route. But, the low price may be accepted only by a LCC. The analysis concerning the effect of a LCC being present on a route is the subject of Section 6.5.3.

For the Wenzhou route, if the airlines could react ahead of the HSR start of operation, they could find an airfare that prevents substantial loss.

In the Beijing case, since it is a very popular route (its passengers made up about 20% of the total passengers in NKG before the HSR started in 2010), no airlines gave up
this market segment. From the airport perspective, the airfare reduction will bring benefits for all stakeholders, because it attracts more passengers. For airlines, the better action is to reduce the airfare in advance of HSR entering the market. In this case, a lower airfare will help in reducing the airline deficit. If the airlines are responding to the HSR pressure after HSR has already started operation, then the airlines would prefer to do so with higher airfares and lower frequency. Therefore, in this situation, the airport is more likely to reduce its airport charge to the airlines.

Notably, the Changsha route shows similarities to Beijing, however its traffic volume is only about half of the route to Beijing. Therefore, if the airlines lower their airfares before HSR enters the market, there is no need for reduced frequency as well. On the contrary, the demand could keep the higher load factor of the flights and the airport and the airlines would both benefit from it.

Finally, comparing all these seven routes, the impact of HSR on the air travel market is the least on the Nanjing-Qingdao route. As shown in Scenario 1, when the airfares drop by 20% (after HSR entering the market), Qingdao passengers only dropped 19%. If the airlines could respond to HRS, by reducing the airfare, before HSR is starting its operation, the airlines and the airport would experience benefits in the presence of the competition.

The HSR entering the market brought different impacts on the air travel market for different routes. The model structure highlights possible reasons for these differences. The demand change comes from HSR pressure, resulting in airfare changes and changes of flight frequencies, and subsequently of the load factor, which affects the number of passengers. For instance, if an airline decides to leave the market, the number of passengers travelling with this airline will be zero, although there is still some latent demand. Those passengers will transfer to other airlines or to the HSR. The next scenarios,
applied at the airline level, explore different parameters for different airlines, in order to assess their combined effect.

6.5.3 Combined Effects at the Airline Level

This section investigates the impact of different airline actions.

In China there are three types of airlines:

1) Main Full Service Airlines (MFSA), serving both domestic and international routes: Air China (CA), China Southern (CZ) and China Eastern (MU). Up to 1990s, they were all government owned. However, now these are independent companies, but to some degree still under government control;

2) Regional Full Service Airlines (RFSA), whose services only cover some areas around their base airports. Generally speaking, those airlines are joint investments of the local government and the main full service airlines. Few of them are fully private;

3) Low Cost Carriers (LCC), serving a modest market in China and only on very limited routes. In NKG, there are only few routes served by LCC. The slow development of LCC is partly because of the government control and the low awareness of passengers in regard to these services.

Based on a previous study on LCC, it was found that the pressure of a LCC completely changes the market situation on a route. The impact of airline competition on the airport will be explored next and further in Chapter 7. The route Nanjing-Qingdao is selected here because on this route there are two airlines with characteristics covering both FSA and LCC. China Eastern (MU) is a traditional FSA and Sichuan Airline (SC) is a regional airline, with some characteristics of LCC, particularly much cheaper airfares.
So the system dynamics model is used to simulate the different airfares of the two airlines to find the impact on the airport revenues.

Additionally, different SLFs are applied to different airlines. The Traffic Volume Module (Chapter 5) provides explanations of how the airlines decide to change the frequency of their flights. The model assumes that for SLF reaching 100% the airline will increase their flights, while if the SLF is less than a threshold then they will decrease the number of flights. Normally, the SLF threshold is decided by the airlines based on their break-even point, depending on the route and type of aircraft.

Different initial airfares and SLF for MU and SC are arbitrarily set in the SD model as starting values. Initial SLF for MU is 0.7, while it is 0.88 for SC. The initial airfare of MU is 546 ¥ (0.7*780, where 780 represents the full price), while SC would charge a lower airfare 390 ¥ (0.5*780), which is even lower than the price of HSR on this route (400 ¥ for the second class). The simulation results are given in Table A6.16 in Appendix A6 for the following six cases:

Case 1 - baseline, without HSR; SLF MU=0.7 and SLF SC =0.88 (airfare = ¥546 for MU and ¥390 for SC).

Case 2 - with HSR; airfare unchanged and no other action of airlines.

Case 3 - with HSR; airfare reduced by 20% after HSR entering the market (¥390 for MU and ¥234 for SC); frequency unchanged.

Case 4 - with HSR; airfare reduced by 20% after HSR entering the market (¥390 for MU and ¥234 for SC); frequency changed.

Case 5 - based on case 4, the airport reduces the airport charge by 10% for both airlines, and they both pass the decrease to the passengers (APP=1: Airline Pass Percentage=100%, means airline fully passed the change of airport charge to the airfare)

Case 6 - based on case 4, the airport reduces the airport charge by 10% for both airlines, and both airlines keep the decrease as profit (APP=0: Airline Pass Percentage=0, means airline does not change airfare when airport charge changes).
Figures 6.17 to 6.19 (Table A6.16, Appendix A6), show the impact of HSR on the airport and airline activities at airline level.

**Note:** China Eastern-MU; Sichuan Airline-SC

**Figure 6.17-** Impact on the Number of Passengers on the Qingdao Route at Airline level

**Figure 6.18 Impact on the Number of Flights on the Qingdao Route at Airline Level**
When the HSR enters the market, the airline that can offer the lower airfare (SC for the Qingdao route) is more competitive in capturing passengers on that route. If the airfare could go lower than the HSR ticket price, the airline even could attract the passengers from HSR. For example, Table A6.16, Appendix A6, shows that more passengers are flying by SC when SC reduced its airfare, while MU will lose its market share to some degree even if it reduces the airfares.

In terms of the impact of HRS on airport revenues, as expected, airfare reductions would bring higher revenues to the airport. On the other hand, the airport is unlikely to get additional revenues from the full service airline, MU, which has high airfares, even when the airport reduces its charges. In such a situation, SC becomes more important for the airport. The airport may prefer to propose lower airport charges to SC to encourage it to provide lower airfares and higher frequency to their passengers. These measures are required to attract more passengers, through which the airport could increase their revenues. From the point of view of SC, it would have higher power to negotiate with the airport to get more benefits. The scenario analysis indicates that if there are LCC
operating on a route, the airport will take different actions towards the different airlines in order to get higher revenues.

6.5.4 Sensitivity Analysis

The results indicate that variability in airport revenues can be explained by the timing of the measures adopted and higher seat utilization (Table 6.8). Whereas the Beijing route has a strong contribution to the airport revenues, Tianjin and Wuhan routes are negatively associated with airport revenues. Of particular relevance is the price elasticity of demand, which indicated that the more elastic the demand, the greater the reduction in airport revenues.

<table>
<thead>
<tr>
<th></th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B (million ¥)</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>-381.387</td>
<td>60.959</td>
<td>0.000</td>
</tr>
<tr>
<td>Reactive vs Proactive</td>
<td>12.289</td>
<td>2.153</td>
<td>0.227</td>
</tr>
<tr>
<td>Initial SLF</td>
<td>481.933</td>
<td>76.257</td>
<td>0.589</td>
</tr>
<tr>
<td>Beijing</td>
<td>22.755</td>
<td>6.236</td>
<td>0.312</td>
</tr>
<tr>
<td>Qingdao</td>
<td>-10.062</td>
<td>3.740</td>
<td>-0.138</td>
</tr>
<tr>
<td>Tianjin</td>
<td>-29.551</td>
<td>5.440</td>
<td>-0.405</td>
</tr>
<tr>
<td>Wuhan</td>
<td>-25.460</td>
<td>3.872</td>
<td>-0.349</td>
</tr>
<tr>
<td>Price Elasticity of Demand</td>
<td>-13.305</td>
<td>4.860</td>
<td>-0.119</td>
</tr>
</tbody>
</table>

Note: $R^2_{adj} = 0.807; F = 66.439 (p<0.001)$

Similarly, when summarising the determinants for all airline revenues (Table 6.9), the higher the cross-elasticity of demand with respect to HSR cost and time, the higher the airline revenues, suggesting of a substitution effect. Again, the Beijing route has the higher proportion of the airline revenues, given the market share of the air transport at the NKG airport.
Table 6.9 Sensitivity Analysis Results for Airline Revenues

<table>
<thead>
<tr>
<th></th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B (million ¥)</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>88.274</td>
<td>12.195</td>
<td>0.000</td>
</tr>
<tr>
<td>Reactive vs Proactive</td>
<td>62.572</td>
<td>10.134</td>
<td>0.156</td>
</tr>
<tr>
<td>Beijing</td>
<td>469.523</td>
<td>14.972</td>
<td>0.869</td>
</tr>
<tr>
<td>Wuhan</td>
<td>-68.487</td>
<td>14.951</td>
<td>-0.127</td>
</tr>
<tr>
<td>Changsha</td>
<td>78.347</td>
<td>16.532</td>
<td>0.145</td>
</tr>
<tr>
<td>Wenzhou</td>
<td>-75.262</td>
<td>15.489</td>
<td>-0.139</td>
</tr>
<tr>
<td>HSR elasticity</td>
<td>105.027</td>
<td>18.781</td>
<td>0.164</td>
</tr>
</tbody>
</table>

Note: $R^2_{adj} = 0.92$; $F = 241.431$ (p<0.001)
CHAPTER 7 EFFECT OF LOW COST CARRIERS ON

NANJING AIRPORT

In this chapter, the effect of low cost carriers (LCCs) on the airport is investigated. The level 2 model with competition, developed in Chapter 6, is applied to Nanjing Airport in order to examine the impact of LCC entry on airport revenue and the role of LCC when HSR is present. In this chapter, the relationship between FSA and LCC is simulated and additional scenarios are set to find out whether growth of LCC activity at airports can be translated into an actual benefit of increased revenues. The chapter concludes with a number of recommendations.

7.1 Low Cost Carriers (LCCs): Features and Expansion

The business model of LCC, first adopted by Southwest Airlines in the USA in the 1970s (Doibruszkes, 2011; Doganis, 2006), has been employed by airlines in many markets as a competitive alternative to the traditional full-service airline (FSA, also referred to as “legacy carriers” or “network carriers”) operation. In general, LCCs provide low-fare air travel services that eliminate various “frills” such as free meals and in-flight entertainment offered by FSAs (Barrett, 2004). Other main features of the LCC business model include: simple fare scheme; point-to-point service and use of uncongested secondary airports with 20–30 min aircraft turnaround time; direct ticket sale and internet-based booking; no seat assignments; high flight frequency; single aircraft type or limited range; high aircraft utilisation and seat capacity; and competitive employee wages with profit-sharing arrangements (Gillen and Morrison, 2003; Gross and Schroder, 2007; Graham 2013; Luck and Gross, 2013). These operational characteristics have enabled LCCs to achieve substantially lower unit costs than FSAs, which has turned LCCs into
leading players in many liberalised/developed markets, such as Southwest and JetBlue in the US, Ryanair and EasyJet in Europe, and Lion and AirAsia in Asia (Dobruszkes, 2011; Zhang et al., 2008). As put by Dobruszkes, “The geography of low-cost networks is to a large extent the geography of EU air transport liberalization” (ibid. p. 249).

The rapid development of LCC worldwide confirms their importance as a sector of air transport. LCCs represent 25% of the passenger market in North America (measured as pax), and over 20% in Europe (Francis et al., 2006; Zhang et al., 2008). In Europe, LCCs have led to an important growth of air supply with half of the 183 million seats created between 1995 and 2004 due to LCC (Dobruszkes, 2011). Ten years ago, many European airports were already specialised in low-cost supply: London’s Stansted and Luton, Belfast International, Frankfurt Hahn, Gerona had LCC shares above 90% of their activity due to LCC usage (ibid, p. 255).

Even in Asia, considered to lag behind North America and Europe (Zhang et al., 2008), LCCs accounted for 15% of the region’s fleet and slightly over 20% of seat capacity in 2014.12 In Australia, after several failed attempts at the beginning of this century (Forsyth et al., 2006), more LCCs have entered the market and now they are experiencing a “boom”.13 The local conditions (a small number of high-density links between the capital cities, plus a fringe of other routes) meant that LCCs found it difficult to access market niches “in which they can operate uncontested” (p.284). Similarly in Latin America, because there are no secondary airports in major capitals (unlike the US and Europe) or low cost terminals (such as Kuala Lumpur and Singapore in Asia), the penetration remained modest.14 In all cases, the LCC airlines had an impact on the market

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14 http://www.tnooz.com/article/low-cost-carrier-latin-america/
and on demand. Elwakil and Dresner (2013) showed that yearly, about five million Canadian passengers diverted to US airports, primarily because of LCCs. In Spain, managers of tourist establishments had a positive view of the role of the LCCs (as opposed to network carriers) in the economic development of the region (Castillo-Manzano et al., 2011). LCCs also changed the relationships of airlines with the airport (Graham, 2013). Despite the complementarity and mutual dependence of the two, not enough attention has previously been given to issues that linked airports and airlines. As stated by Graham (2013): “the academic literature is far less clear and conclusive about the overall impacts of LCC operations at airports and the extent to which airports benefit from LCCs, particularly in the long-term, and this suggests that more studies are needed.” (p. 66)

### 7.1.1 The Development of LCC in China

In China, LCCs are a much more recent phenomenon (Zhang et al., 2008). It was not until 2005 that the first LCC – Spring Airline – launched its service based in Shanghai. During the same year, Okay Airways based in Tianjin, also positioned itself as an LCC and operators believed that this model would help the airlines to secure a slice of the market dominated by their state-owned counterparts. However, seven months after launching the program, Okay Airways renounced its LCC model due to the high percentage of uncontrollable costs in the total costs (Zhang and Meng, 2005; Zhang and Lu, 2013) such as taxes on the purchase of aircraft, fuel costs, and airport charges.

In addition, China’s aviation environment has been less friendly to LCCs and private carriers as manifested by the regulated market access (Zhang and Lu, 2013). The market is favourable to existing airlines because of the high costs incurred in recruiting pilots and other skilled personnel from other airlines. This is due to restrictions put on the movement of employees between airlines (Zhang et al., 2008; Zhang and Lu, 2013).
Until 2012, Spring Airline remained the only LCC in China, operating a fleet of 30 aircrafts on more than 40 routes, including flights from Shanghai to Hong Kong and Japan (Zhang and Lu, 2013). Similar to other private carriers, Spring Airline faced restrictions on entry into some lucrative routes and peak time slots. This Shanghai-based LCC had to wait six years before it was allowed to fly the Shanghai-Beijing route in 2011. In December 2006, the airline offered a “1-yuan promotional price”, which also caused trouble with government officials, responsible for the price regulation regime.\(^5\) Spring Airline maintains a high load factor of about 95% that is well higher the industry average of 70%, by offering low airfares. Spring Airline has tried many ways to save costs, including the use of its own computer reservation system and encouraging online sales. Cost savings also come from improving the daily aircraft utilisation rate to 12–13 hours, compared to 9–10 hours for China’s traditional airlines (Lin, 2012). Until 2014, Spring Airline carried about 3% of the total domestic air traffic volume.\(^6\)

In 2012, a new LCC started to operate flights in the Chinese domestic market. West Airline, based on Chongqing and Zhengzhou, announced a change to LCC in June 2013.\(^7\) United Airline, based on Beijing and Fushan and 9 Air, based on Guangzhou, joined the few existing Chinese LCCs in 2014.\(^8\)

Currently, there are four LCCs in China - Spring Airline (9C), West China Airline (PN) belonging to Hainan Airline, China United Airline (KN), belonging to China East Airline and 9 Air (AQ). China United Airline and West China Airline resemble somewhat state-owned airlines in their structure and operation (before 2012, China’s aviation market was still dominated by Air China, China Southern, China Eastern, and Hainan

\(^5\) [https://en.wikipedia.org/wiki/Spring_Airlines](https://en.wikipedia.org/wiki/Spring_Airlines)
\(^6\) [http://www.iata.org/pressroom/pr/pages/2012-12-06-01.aspx](http://www.iata.org/pressroom/pr/pages/2012-12-06-01.aspx)
Airlines and their subsidiaries, commanding a market share of more than 90% in both passenger and cargo markets). By contrast, Spring Airline and 9 Air are private airlines (Zhang and Lu, 2013). Whereas the global LCC industry has accounted for 17% of the passenger traffic, in China it remained at only 8-9% (IATA, 2013).

7.1.2 Conditions and Impact of the LCC in China

The development of LCCs has been constrained by regulatory barriers like market access, airport slot and aircraft purchases. (Zhang et al., 2008). However, there is a large proportion of low-income population in China, compared with the 8% market share of LCC (Fu et al., 2015). This suggests that the potential demand for LCCs in China is not tapped into as yet.

Numerous studies have confirmed the effect of LCC entry in reducing airfares and their positive effect on traffic demand in the US and European air markets; two notorious or well-known examples are Southwest and Ryanair (Alderighi et al., 2012; Graham and Dennis, 2010; Morrison 2001). Zhang et al. (2008) explained that the effect of LCCs in Asia may be very similar, which was partially confirmed by Chung and Whang’s (2011) findings on Korean Island tourism. However, the LCCs effect has only recently been studied and reported in China, thus there is limited evidence.

Zhang et al. (2008) indicated there are many barriers for low-cost start-ups to enter the market in China. In comparison to the US, Canada and the EU, many more aspects of the industry are regulated in China, including aircraft purchase, pilot acquisition, fuel purchase, airport charges, route entry and pricing. These regulatory barriers make LCCs difficult to implement in China and therefore limit their growth.

In order to investigate the impact of Spring Airline on the route passenger volumes, Zhang and Lu (2013) applied a gravity model. Their sample considered 35 routes between 2004-
2010 which between Shanghai and other domestic cities, including the capitals of most provinces. The conclusion was that Spring Airline has contributed to an increase in passenger volume by 23% in the domestic travel on these routes, holding other factors constant. Zhang and Lu (2013) also found that when the jet fuel price increased by $1 per gallon, the number of passengers carried dropped by 6%. They concluded that the tourism and economic benefits brought about by LCCs should be the driving force for change in the air transport policies in China.

Fu et al. (2015) also examined Spring Airline and used monthly panel data on 514 city-pair routes in the domestic market (the top 500 routes plus a few smaller routes served by Spring Airline from August 2008 to July 2012) to find out their impact in the Chinese market. Spring had a statistically significant negative impact on the average yield of all FSAs on every route. This confirms that competition from Spring Airline did force FSAs to lower their ticket prices. Specifically, the presence of Spring Airline reduced the fare of Air China by 5.1%, the fare of China Eastern by 3.4% and the fare of Hainan airlines by 6.2%. Overall, FSAs’ fares were reduced by 2.3% due to the competition from Spring Airline (Fu et al., 2015). Such a fare reduction is rather small compared to those observed for leading LCCs, such as Southwest in the US, and Ryanair in Europe.

The research conducted by Fu et al. (2015) also highlighted an average fare reduction per route of US$7.7 (or ¥53) for an average distance of 1,268km. This limited effect may be explained by Spring Airline’s low capacity on individual routes. Although the carrier has been expanding its network and fleet, its capacity on individual routes tends to be low (<20%), especially on dense routes dominated by large FSAs. Although at the moment dominant FSAs are not under great pressure to respond with a significant price cut, this situation may change in the near future.
7.1.3 LCC at Nanjing Airport

In 2015, four LCCs provided services on 10 routes to and from Nanjing Airport (NKG). The routes are listed in Table 7.1 and LCCs are compared to the FSA; the LCC market share is modest, with only one flight a day from Nanjing on each route. It is also important to note that among these 10 routes, Nanjing-Ordas is a new route only operated by LCC.

### Table 7.1 LCC Routes in Nanjing (One-Way)

<table>
<thead>
<tr>
<th></th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
<th>Ordas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance (km)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,630</td>
<td>747</td>
<td>1,526</td>
<td>1,533</td>
<td>1,756</td>
<td>1,255</td>
<td>1,305</td>
<td>1,990</td>
<td>2,300</td>
<td>1,690</td>
</tr>
<tr>
<td>Published economy airfare (¥)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,460</td>
<td>750</td>
<td>1,380</td>
<td>1,460</td>
<td>1,650</td>
<td>1,180</td>
<td>1,280</td>
<td>1,850</td>
<td>2,180</td>
<td>1,350</td>
</tr>
<tr>
<td>LCC frequency (flight/day)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>FSA frequency (flight/day)</td>
<td>5 (by 3 FSAs)</td>
<td>6 (by 3 FSAs)</td>
<td>13 (by 5 FSAs)</td>
<td>6 (by 6 FSAs)</td>
<td>4 (by 4 FSAs)</td>
<td>18 (by 5 FSAs)</td>
<td>10 (by 5 FSAs)</td>
<td>3 (by 3 FSAs)</td>
<td>2 (by 2 FSAs)</td>
<td>0</td>
</tr>
</tbody>
</table>

7.2 LCC Model Structure

The focus on low cost carriers (LCC) in this chapter enables us to find out how the airport could provide a varying price scheme to the airlines, in order to arrive at “win-win” situation under different market structures.

The model described in Chapter 6 focused on the competition between FSA and another transport mode – HSR. But, as already indicated above, China has been experiencing a rapid development of LCCs since 2012, which may have an additional effect on the airport, especially on those markets where HSR operates. Therefore, new scenarios are set to investigate the impact of competition between FSA and LCC on airport revenues. Because only changes in total passenger volumes will affect airport revenues, the passenger numbers transferring between various airlines do not need to be
considered. Thus, in this chapter, airline cross-price elasticity is excluded and the structure of airline competition is not detailed either. This means that model structure in this chapter is the same as the model in Chapter 6 (see Figure 6.2). However, an LCC switch variable is added to indicate its presence on the route. Initial values of some variables for LCC are also different, e.g. LCC’s seat load factor (SLF) is higher and its airfare is lower compared with FSA.

In this model, the total demand change for each route is calculated using the own price elasticity at route level and the average airfare for the route.

\[
\text{Route Price Elasticity} = \frac{\% \text{ Change in Quantity Demanded on the Route}}{\% \text{ Change in Route Average Airfare}} \quad 7-1
\]

As indicated in Table 7.1, ten routes where LCCs operate are all medium- to long-haul routes. Based on the conclusion of the report IATA (2007), which developed some general guidelines on the use and application of airfare elasticities, this study uses different elasticities by applying the relevant multiplier. Therefore, the value of route price elasticity in this model ranges from -1.14 to -1.425.19 The individual values for each route, taking account of the mix of business and non-business travellers, are provided in Table A7.1 in Appendix A7.

When a LCC enters a specific route, the airline market shares and route average airfare will change.

\[
\text{Route Average Airfare} = FSA \text{ Airfare} \times FSA \text{ Market Share} + LCC \text{ Airfare} \times LCC \text{ Market Share} \quad 7-2
\]

19 Based on IATA (2007), this value = base multiplier for route level (-1.2 to -1.5) * Geographic Aviation Market multiplier for Asia (0.95)
\[
LCC\ Market\ Share\ for\ a\ route = \frac{LCC\ Demand}{Total\ Route\ demand}
\]
\[
= (LCC\ Frequency \times LCC\ Seat\ Capacity\ per\ flight \times LCC\ SLF)/(LCC\ Frequency \times LCC\ Seat\ Capacity\ per\ flight\ \times LCC\ SLF + FSA\ Frequency \times FSA\ Seat\ Capacity\ per\ flight \times FSA\ SLF)
\]
\[
Route\ LCC\ demand = Total\ Route\ Demand \times LCC\ Market\ Share
\]

Route FSA demand is calculated in the same way. In these scenarios, LCC seat load factor is assumed to be 93%, which is the average for Spring Airline from their annual reports (http://help.ch.com/images/IntoSpring/invester). The other input data is obtained from historical statistics.

7.3 Scenario Setting

A number of different scenarios were simulated to test the effect of LCCs on the Nanjing Airport’s revenues.

7.3.1 Impact of LCC on Long-Haul Routes without HSR

Until 2015, in Nanjing Airport, LCCs have provided services on long-haul routes with distance during 700km to 2300km (see Table 7.1, nine routes out of ten above 1200km). As shown in Chapter 6, the impact of HSR on these long-haul routes was small and therefore it could be ignored. Consequently, for these 10 routes, the focus is on the impact of LCCs on the NKG airport’s revenues.

Two scenarios are tested:

- **Scenario 1** Impact of LCC entry on the airport activity when FSA airfares are unchanged
In this scenario, it is assumed that FSAs operating the same routes with LCCs do not change their airfares.

- **Scenario 2 Impact of LCC entry on the airport activity when FSA airfares are changed**

In Scenario 2, when a LCC airline enters the market, it is expected that FSAs operating on this route will all respond by changing their airfares. This is based on findings from the research of Fu et al. (2015), who showed that FSAs reduced airfares by an average of 2.3% (range from 0-6.2%) when Spring Airline started their competing operation on several domestic routes. In this scenario, the average level of 2.3% was applied for the decrease in FSAs’ fares, following the competition from LCCs on those routes. The results are presented next.

7.3.1.1 Impact at the airport level

**Scenario 1**

The simulation here compares conditions before and after LCCs started operation on the 10 domestic routes. It is assumed that the initial airfares of FSAs are 70% of the standard published price, while LCCs are only 40%. As indicated, Nanjing-Ordas is a new route only operated by LCC. It is certain that this new market opportunity could generate new demand for the airport. Therefore, in order to analyse the impact of LCCs on existing routes, the simulation is undertaken only for nine routes, excluding Nanjing-Ordas. Results are presented in Table 7.2. The analysis including the route Nanjing-Ordas is presented in Table 7.3.
Table 7.2 Comparison of Impacts before and after LCC Entry on Nine Routes, Excluding Ordas (FSAs Fares Unchanged)

<table>
<thead>
<tr>
<th></th>
<th>Before LCC entry (FSA airfare 0.7*price cap)</th>
<th>After LCC entry (FSA airfare 0.7<em>price cap; LCC airfare 0.4</em>price cap)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>6,318.399</td>
<td>6,521.222</td>
<td>3.21%</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>313.146</td>
<td>324.493</td>
<td>3.62%</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)*</td>
<td>5,649.213</td>
<td>5,654.706</td>
<td>0.10%</td>
</tr>
<tr>
<td>Total FSA pax (1000’s pax)</td>
<td>6,318.399</td>
<td>6,065.606</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Total FSA revenue (million ¥)</td>
<td>5,649.213</td>
<td>5,415.288</td>
<td>-4.14%</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>48,240</td>
<td>51,300</td>
<td>6.34%</td>
</tr>
<tr>
<td>Airline revenue per flight (million ¥/flight)</td>
<td>0.117</td>
<td>0.110</td>
<td>-6.20%</td>
</tr>
</tbody>
</table>

* In this thesis, it is assumed that airline revenue = ticket sale revenues - airport aeronautical charges.

Table 7.2 shows that on these nine routes, the number of annual airport passengers increased by 3.21% due to the opportunities created by the LCCs entering the market that delivered more flights and lower airfares (30% lower than FSA). This increase in passenger numbers is due to LCCs, including generated demand and a demand shift from FSA. Accordingly, the airport revenues increased by 3.62% because of the overall increase of passenger and flights volumes. On the other hand, a decrease of 4.0% in FSA passengers results in FSA revenue decreasing by 4.14%, since LCCs attracted passengers from FSA by lower airfares. In terms of the total airline revenues, there was only a 0.1% increase; yet, airline revenue per flight decreased by the 6.2% although the passengers increased by 3.21%. This is due to the increase in LCC passengers, which leads to decrease in airline unit revenue because of the average low airfare of a LCC. Again, as noted before, in this chapter, airline revenues only refer to the remaining revenues after deducting the total airport fees paid to the airport from the ticket sales. Other corresponding costs incurred by the airlines, such as fuel consumption and maintenance of the aircrafts, are not considered in the model. For airport operation, there is a considerable 6.34% increase in the number of flights.
Next, Table 7.3 presents the comparison of airport indicators with the Nanjing-Ordas route. As expected, Table 7.3 shows more passengers are using the NKG airport, which will bring more revenues to the airport. Comparing Tables 7.2 and 7.3, it is found LCC entry into the existing market increases the overall demand by 3.21%, and the airport revenue is increased proportionally by 3.62%; whereas entering a new market increases the demand by 3.76% and airport revenues by 4.18%. Therefore, LCC’s entry on the market may be appealing to the airport. The new opportunities brought to the airport by developing new market segments, currently not considered by FSA, may increase the number of flights much more than on existing routes. On the other side, the presence of LCCs has a negative impact on the FSAs’ demand and revenues, due to the airline competition. Their total passengers and revenues decreased by 4% because of the lower airfares applied by LCC; therefore, if LCCs want to operate their business in a financially sustainable way, they must be efficient and keep their operation costs at low levels. As pointed out by Zhang & Lu (2013) and Zhang & Meng (2005), the failure of Okay Airways was a result of its high costs.

<table>
<thead>
<tr>
<th></th>
<th>Before LCC entry (FSA airfare = 0.7*price cap)</th>
<th>After LCC entry (FSA airfare = 0.7<em>price cap; LCC airfare = 0.4</em>price cap)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>6,318.399</td>
<td>6,555.831</td>
<td>3.76%</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>313.146</td>
<td>326.243</td>
<td>4.18%</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)*</td>
<td>5,649.213</td>
<td>5,672.267</td>
<td>0.41%</td>
</tr>
<tr>
<td>Total FSA pax (1000’s pax)</td>
<td>6,318.399</td>
<td>6,065.606</td>
<td>-4.0%</td>
</tr>
<tr>
<td>Total FSA revenue (million ¥)</td>
<td>5,649.213</td>
<td>5,415.288</td>
<td>-4.14%</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>48,240</td>
<td>51,640</td>
<td>7.05%</td>
</tr>
<tr>
<td>Airline revenue per flight (million ¥/ flight)</td>
<td>0.117</td>
<td>0.110</td>
<td>-6.20%</td>
</tr>
</tbody>
</table>
However, in this scenario, it is assumed FSAs do not respond to LCC entry in any way. In the following scenario, actions taken by FSA in competition with LCC are simulated.

**Scenario 2**

Scenario 2 simulates the impact of LCC entry on airport revenues, when FSA airfares are reduced by 2.3% or 6.2% in response to LCC entry on the market. These values are anchored in the results provided by Fu et al. (2015), but wider distributions may also be applied. As before, LCCs airfares are considered at the level of only 40% of the price cap. Table 7.4 shows the results.

### Table 7.4 Impact on Activity and Revenue of FSAs Fare Changed After LCC Entry on Nine Routes

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Case 2</th>
<th>% Change</th>
<th>Case 3</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>After LCC entry (FSA airfare 0.7<em>price cap; LCC airfare 0.4</em>price cap)</td>
<td>After LCC entry (FSA airfare decreased by 2.3%; LCC airfare 0.4*price cap)</td>
<td>(comparing case 2 with 1)</td>
<td>After LCC entry (FSA airfare decreased by 6.2%; LCC airfare 0.4*price cap)</td>
<td>(comparing case 3 with 1)</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>6,521.222</td>
<td>6,620.854</td>
<td>1.53%</td>
<td>6,779.852</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>324.493</td>
<td>328.723</td>
<td>1.30%</td>
<td>335.472</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>5,654.706</td>
<td>5,632.126</td>
<td>-0.40%</td>
<td>5,577.319</td>
</tr>
<tr>
<td>Total FSA pax (1000’s pax)</td>
<td>6,065.606</td>
<td>6,167.908</td>
<td>1.7%</td>
<td>6,332.578</td>
</tr>
<tr>
<td>Total FSA revenue (million ¥)</td>
<td>5,415.288</td>
<td>5,393.461</td>
<td>-0.40%</td>
<td>5,340.488</td>
</tr>
<tr>
<td>Total LCC revenue (million ¥)</td>
<td>239.418</td>
<td>238.665</td>
<td>-0.31%</td>
<td>236.831</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>51,300</td>
<td>51,300</td>
<td>0.00%</td>
<td>51,300</td>
</tr>
</tbody>
</table>
The results in Table 7.4 show that the range of FSA airfare reduction applied here may be insufficient for FSA to beat LCC. Overall a 6.2% decrease of FSA airfares increased the airport revenue by only 3.38% and the decrease of 2.6% modified the airport revenue by 1.3%. Although airport revenue is not very sensitive to this range of price reductions, the FSA-LCC competition has a beneficial impact on the airport revenues.

For FSAs, a 6.2% decrease in airfares increased their passengers by 4.4% to 6,335 million, which is slightly more than 6,318 million before LCC entry (see Table 7.2). Yet such increase in total demand generated from lower airfares cannot compensate for their lost revenue (-1.38% decrease in Table 7.4). Unsurprisingly, when FSA decrease their airfares, the LCCs missed some of their passengers and revenues as well.

Comparing Table 7.2 and 7.4, it appears that the pressure of LCC entry may have a limited impact on FSA for those nine routes and it is hard to trigger a “fierce price war” between them because both types of airlines’ revenues decreased when the FSA airfares were reduced. However, since LCCs are more vulnerable to revenue losses and their capacities are limited, a small decrease in revenue for LCCs may be “terminal” to them, eliminating them from operation. Since the unit cost is key to LCCs, they require higher seat-load factors (SLFs), which means adequate demand. Additional impacts on FSA and LCC are analysed later in Section 7.3.2.

Overall, the LCCs’ entry brings benefits to the airport, although they may be not substantial at this low level of presentation in China. An uncongested airport may prefer LCCs to develop operations on new routes, in addition to entering existing routes. However, as indicated, the flight volume increased more than the passenger volume and airport revenues (7% compared with about 4% in Table 7.3). In Nanjing airport, for these ten routes, LCCs are flying during off-peak times, without causing or contributing to the
airport congestion. But further increases in the flight volumes may be translated into substantial delays for an airport, especially if already congested.

7.3.1.2 Impact at the route level

Section 7.3.1.1 compared the impact of LCC entry at the airport level. Nevertheless, for different routes the market structure, frequency, aircraft fleets and airfares are all different. Therefore, applying the above scenarios (Scenario 1 and 2) at the route level is essential in this analysis, in order to identify local effects.

- **Scenario 1 Impact of LCC entry on the airport activity when FSA airfares are unchanged (differentiated by route)**

The simulation results are compared for nine different routes. Ordas is a new route and because the demand cannot be entirely attributed to LCC, this route was excluded from the following analysis.

- **Scenario 2 Impact of LCC entry on the airport activity when FSA airfares are changed (differentiated by route)**

**Scenario 1**

At the airport level, it has been found that LCCs’ entry has a positive effect on the airport passengers and revenues, although this is not substantial for the circumstances analysed. The analysis of the nine routes revealed that the biggest increase in the passenger volume was on the Hailar route with 10.16%, while the smallest increase is on the Guangzhou route with 1.52% (Table A7.1 in Appendix A7).

Figure 7.1 (a to c) presents the number of passengers, flights and revenues for airports and FSA airlines before and after LCCs start operating on the nine routes, as well as relative changes in indicators.
LCC’s impact on nine routes
(before entering the market)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual flight (’00 flights)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total FSA revenue (10 million ¥)</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Total airport revenue (million ¥)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total passengers (10,000s pax)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LCCs’ impact on nine routes
(after entering the market)

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total annual flight (’00 flights)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total FSA revenue (10 million ¥)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total passengers (10,000s pax)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 7.1-a Indicators for Nine Routes before LCC Enter the Market

Figure 7.1-b Indicators for Nine Routes after LCC Enter the Market
Table 7.1 indicated the airline frequency of flights/capacities across these nine routes, which explains why Nanjing-Hailar has the highest penetration of LCCs with 23.1% of the market, while it is only 3.1% in Nanjing-Guangzhou (see Table A7.1, Appendix A7). The result reveals that the impact of LCCs on the demand and airport revenue is significantly dictated by the market share or capacity of LCCs, and that larger market shares of LCCs have positive effects on airport passengers and revenue (e.g. Hailar - increase of 23.61% in annual flights).

In terms of the airport revenue, the increases are less dramatic. The largest growth is again on the Hailar route (12.22%), while only 1.67% on the Guangzhou route. The relations between airport revenue and the traffic volume, including passenger and flight volumes, can explain this variation. The largest relative increase in flight volumes is on Hailar (see Table A7.1, Appendix A7). Although smaller in absolute numbers, requests for additional flights may pose operation challenges for the airport, if their temporal profile conflicts with the airport runway capacity. Therefore, increasing airport revenues
through larger numbers of passengers is preferred by the airport, to revenue increases through additional flights.

However, because the original market demands vary, although the relative increase in airport revenue is highest in Hailar route, the highest absolute increase is on the Guangzhou route.

In terms of airline revenues, as indicated in 7.3.1.1, at the airport level the LCC entry has a negative impact on the FSAs’ revenues. For individual routes, the most affected route is Hailar with a decrease of 14.2%, and the smallest decrease is on the Guangzhou route with 1.5%. This implies that on routes with intense flight activity (e.g. Guangzhou) and limited capacity of LCCs, the risks for FSA to lose their market share are diminished. On the other hand, it indicates that LCCs may prefer to enter routes with lower density of flights (e.g. Hailar).

**Scenario 2 Impact of LCC entry on the airport activity when FSA airfares are changed (differentiated by route)**

The simulation results are shown in Appendix A7 (Tables A7.2 –Table A7.5) and the relative changes presented in Figures 7.2 and 7.3. The airport would benefit if the FSAs decreased their airfares, because this would bring an increase of around 3%-4.2% to the passenger volume and airport revenue for all routes. Table A7.3 in Appendix A7 indicates that more than one factor impacts on the passenger volume; distance and market share of LCCs similarly contribute to slight demand differences, with shorter distances and larger market shares of LCCs having positive effects.
As indicated in Section 7.3.1.1, reductions in FSA airfares also lead to revenue losses for both FSAs and LCCs. However, FSAs could “beat” LCCs by regaining market share through lower airfares (for routes such as Fuzhou, Shenzhen, Guangzhou and
Chongqing). Tables A7.4 and A7.5 in Appendix A7 show that on these four routes passenger numbers for FSA increased to the level of before LCC entry, while LCC passenger numbers fell because of the FSA airfare cuts (Figure 7.2 and 7.3). Guangzhou, Shenzhen and Chongqing are all busy routes with 10-18 FSA flights per day. Fuzhou, the shortest route, has only six FSA flights per day, and has the lowest airfares among the nine routes. For the remaining five routes, even if FSAs decrease their airfare, they still experience losses, both in passengers and revenue.

In general, LCC capacity is limited, thus, on routes with intense flight activity (e.g. Guangzhou), the risks for FSA (with higher capacity than LCC) to lose their market share are reduced. On the other hand, LCCs may prefer to serve routes with lower frequency of flights and higher prices (e.g. Hailar and Haikou), or develop new markets (e.g. Ordas), because they could obtain larger market share on these routes where it is hard for FSA to compete by decreasing their airfares. In other words, the threat of LCC to FSA is limited on the busy routes or dense routes, e.g. Guangzhou and Shenzhen. On the other hand, it is difficult for LCCs to survive on these dense routes. If more LCCs enter the route, FSA could beat them by triggering a price war, although it will affect FSAs’ own revenue as well.

As indicated, when FSAs reduce their fares, the airline revenues (revenue from tickets sale minus airport charges) on all the routes decrease and changes for LCC and FSA revenues are similar, regardless of the changes in passenger numbers. However, the determinants for revenue reduction are different. The decrease in FSA revenue is led by airfare discounts, while for LCC is due to reductions in passenger numbers. These results complement the evidence presented in Section 7.3.1.1 with differentiated effects for airlines: the same decrease in airline revenue means different things to FSAs and LCCs, because their unit profits are different. Therefore, although FSA airfare discounts reduce
their revenues, this is likely to be an effective strategy to minimise losses (FSAs lose more if the fares remain unchanged) and assist FSAs to maintain their market position, with positive flow-on effects for passengers.

As displayed graphically in Figure 7.2 and 7.3, the effects are proportionally related to the magnitude of change in FSA airfares, with minute effects for 2.3% reduction and slightly more substantial for 6.2%.

7.3.1.3 Sensitivity Analysis

As in the previous chapters, results of 30 sets of simulations with various airfares, revenues, and price elasticities were analysed using multiple regression analysis. The sensitivity analysis for revenues reinforces the findings from the scenarios: short haul routes (β = -0.219) bring higher airport revenues, therefore the airport should encourage LCC competition on those routes where reduction in airport charges and elasticities matter the most, provided there is enough capacity.

Table 7.5 Sensitivity Analysis Results for Airport Revenues at Route Level

<table>
<thead>
<tr>
<th>Route</th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>(Constant)</td>
<td>38.712 10E6</td>
<td>3.5475 10E5</td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>-13,059.969</td>
<td>85.966</td>
<td>-0.219</td>
</tr>
<tr>
<td>Airfare Change (%)</td>
<td>17.710 10E6</td>
<td>15.021 10E5</td>
<td>-0.014</td>
</tr>
<tr>
<td>Price Elasticity of Demand</td>
<td>-0.795 10E6</td>
<td>2.145 10E5</td>
<td>-0.050</td>
</tr>
<tr>
<td>Shenyang</td>
<td>3.580 10E6</td>
<td>1.075 10E5</td>
<td>0.045</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>47.081 10E6</td>
<td>1.079 10E5</td>
<td>0.589</td>
</tr>
<tr>
<td>Changchun</td>
<td>8.980 10E6</td>
<td>1.078 10E5</td>
<td>0.112</td>
</tr>
<tr>
<td>Harbin</td>
<td>2.181 10E6</td>
<td>1.080 10E5</td>
<td>0.027</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>66.648 10E6</td>
<td>1.122 10E5</td>
<td>0.834</td>
</tr>
<tr>
<td>Chongqing</td>
<td>21.880 10E6</td>
<td>1.111 10E5</td>
<td>0.274</td>
</tr>
<tr>
<td>Haikou</td>
<td>0.611 10E6</td>
<td>1.116 10E5</td>
<td>0.008</td>
</tr>
</tbody>
</table>
Compared to Hailar, LCCs operating on Guangzhou and Shenzhen route have the most positive impact on airport revenues (the highest standardised parameter estimates of 0.834 and 0.589).

The airline revenues display the same determinants (Table 7.6). Additionally, high-traffic routes such as Guangzhou, Shenzhen and Chongqing are more immune to LCC competition, given their greater market share that FSAs hold on those routes.

Table 7.6 Sensitivity Analysis Results for Airline Revenues at Route Level

<table>
<thead>
<tr>
<th></th>
<th>Unstandardised Coefficients</th>
<th>Standardised Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
</tr>
<tr>
<td>(Constant)</td>
<td>261.917 10E6</td>
<td>2.486 10E6</td>
</tr>
<tr>
<td>Distance</td>
<td>-9.185.725</td>
<td>615.108</td>
</tr>
<tr>
<td>Airfare Change (%)</td>
<td>111.506 10E6</td>
<td>10.744 10E6</td>
</tr>
<tr>
<td>Price Elasticity of Demand</td>
<td>-26.298 10E6</td>
<td>15.348 10E5</td>
</tr>
<tr>
<td>Shenyang</td>
<td>138.203 10E6</td>
<td>0.769 10E6</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>94.465 10E6</td>
<td>1.771 10E6</td>
</tr>
<tr>
<td>Changchun</td>
<td>270.105 10E6</td>
<td>0.773 10E6</td>
</tr>
<tr>
<td>Harbin</td>
<td>129.403 10E6</td>
<td>0.791 10E6</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>1,132.142 10E6</td>
<td>0.803 10E6</td>
</tr>
<tr>
<td>Chongqing</td>
<td>464.986 10E6</td>
<td>0.795 10E6</td>
</tr>
<tr>
<td>Haikou</td>
<td>697.121 10E6</td>
<td>0.798 10E6</td>
</tr>
</tbody>
</table>

7.3.2 Combined Impact of HSR and LCC on Airport Revenue for Short-Haul Routes

The results from 7.3.1 suggest a positive impact of LCCs on the Nanjing airport revenues on all routes, while the impact on the airline revenues is negative. The flight frequency on various markets is the most important determinant, while distance is not so relevant when LCCs choose to enter a route. As indicated in Chapter 6, it is common for FSAs to decrease their service or quit service on short-haul routes covered by HSR. This raises the question of whether LCCs can survive on those routes.
Currently, in Nanjing, there are no LCCs flying short routes with HSR competition therefore no data for validation, however a number of scenarios can be simulated using the data of the routes presented in Chapter 6. These routes are deemed appropriate for analysis, because they represent short-haul routes covered by HSR. The scenarios in this section will investigate the HSR routes, to find out whether the LCCs could “survive” in the competition with HSR.

As indicated in Section 6.5.2, HSR operation triggered dramatic reductions of the number of passengers (more than 70%) on several air routes (e.g. Wenzhou, Wuhan and Jinan). The NKG airport and the airline revenues from these routes were negatively affected as well. Even if the airlines reduced their airfares to match the HSR price or make it lower, they could not improve their market share and their financial revenues. Consequently, many of the airlines flying these routes had to terminate their services.

In the following section, the routes from Nanjing to Tianjin, Beijing, Changsha and Qingdao are analysed, by comparing operation in the presence of HSR and without HSR. It is assumed that all the routes are operated by one LCC and at least another FSA. The assessment aims to identify if and under what conditions a LCC could survive after HSR starts operating and determines the impact of a LCC on the airport’s revenues under intermodal competition.

Operation data shows that the unit operating cost for Spring Airline 2013 and 2014 was ¥0.32 (AUD0.07) /per Available Seat Kilometre (ASK), while their unit operating revenue was ¥0.38 (AUD 0.08) /ASK (Spring Airline 2013, 2014; Fu et al., 2015), comparable to HSR and about half of an economy fare for the full service airlines (Chapter 6). This is indicative of an efficient operation with low margins. In the following simulation, this input data is used to model the average cost and revenue for LCCs. Table 7.7 shows the HSR prices and airfares on four routes where HSR offers service.
Table 7.7 HSR and Airfare Comparison for Four Routes

<table>
<thead>
<tr>
<th>Distance (km)</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>HSR fare (¥)</td>
<td>444</td>
<td>333</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Full airfare (¥)</td>
<td>1,010</td>
<td>840</td>
<td>780</td>
<td>1,000</td>
</tr>
<tr>
<td>Initial FSA airfare =0.7*full price (¥)</td>
<td>707</td>
<td>588</td>
<td>546</td>
<td>700</td>
</tr>
<tr>
<td>FSA airfare change =0.5*full price (¥)</td>
<td>505</td>
<td>420</td>
<td>390</td>
<td>500</td>
</tr>
<tr>
<td>Initial LCC airfare - matching Spring’s unit revenue (¥)</td>
<td>373</td>
<td>319</td>
<td>210</td>
<td>342</td>
</tr>
<tr>
<td>Airfare = 0.3*full price (¥)</td>
<td>303</td>
<td>252</td>
<td>234</td>
<td>300</td>
</tr>
<tr>
<td>LCC airfare change matching Spring’s unit cost (¥)</td>
<td>314</td>
<td>269</td>
<td>177</td>
<td>288</td>
</tr>
</tbody>
</table>

Scenario 3 Impact of HSR entering the market in the presence of LCC

The following cases are simulated to analyse the impact of HSR on the airport’s activity and revenues when LCCs also operate on the HSR routes. The results are then compared with those of Chapter 6, to separate the impact of LCCs from the effect of HSR:

Case 1 - LCCs operate on the four routes, but without HSR;
Case 2 - LCCs and HSR operate on the routes, but the airlines do not change airfares after HSR entering the market;
Case 3 - LCCs and HSR operate on the routes and the airlines decrease their airfares when HSR enters the market.

The initial airfares and the airfares changed after HSR enters the market are listed in Table 7.7.

7.3.2.1 Impact at the Route Level

Simulation results for each route are shown in Figure 7.4 (Table A7.6 in Appendix A7).

The results suggest that even in the presence of LCCs, with airfares comparable to HSR ticket prices, decreases in the number of passengers, airport revenue and airline revenues occur when the HSR enters the market. However, compared with the results given in Section 6.5.2, the decreases are moderate. This implies that LCCs have a positive effect on the airport facing the competition of HSR and the airport should encourage
participation of LCC on shorter routes. The impact of both HSR and LCCs are likely to diminish the airport and airline revenues; nevertheless, the impact of HSR is stronger (6.5.2 vs 7.3.1).

The four charts in Figure 7.4 also show that LCC airfares matching HSR ticket prices benefit the airport; both in traffic volume and airport revenue (case 3). But, this decrease in airfare diminishes even further the revenues of airlines. Despite substantial differences
in the market shares of FSAs across the four routes, there are no distinct patterns of variation for activity and revenues due to the presence of LCC and HSR.

Section 7.3.2.2 presents these results at the airline level, to assess whether FSAs and LCCs experience similar changes on various routes.

### 7.3.2.2 Impact at the Airline Level

Table 7.8 shows the initial seat load factor (SLF) and the flight frequency for full service and low-cost airlines on the four routes discussed above: Beijing, Changsha, Qingdao, and Tianjin. The simulation results at airline levels are shown in Figure 7.5 (Table A7.7 in Appendix A7). The impact of LCCs on the FSA and on the airport revenue (after HSR enters into the market) is different by route.

<table>
<thead>
<tr>
<th>Route</th>
<th>Initial SLF (%)</th>
<th>Initial frequency (one-way, flights/day)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSA</td>
<td>LCC</td>
<td></td>
</tr>
<tr>
<td>Beijing</td>
<td>84.2</td>
<td>93.0*</td>
<td>16</td>
</tr>
<tr>
<td>Changsha</td>
<td>78.0</td>
<td>93.0*</td>
<td>6</td>
</tr>
<tr>
<td>Qingdao</td>
<td>67.2</td>
<td>93.0*</td>
<td>2</td>
</tr>
<tr>
<td>Tianjin</td>
<td>73.8</td>
<td>93.0*</td>
<td>1</td>
</tr>
</tbody>
</table>

* 93% is Spring Airline annual average SLF. Since no real data could be used for this simulation, the average of 93% Spring Airline is applied for all routes.

The analysis shows that HSR entry has a negative impact on the LCCs as well, however the change in their associated traffic volume and airport revenue is much lower than for the FSAs (Figure 7.5). That implies that there is opportunity for LCCs to compete with HSR. Additionally, in terms of route distance, there is less effect of HSR on LCCs on shorter routes, like Qingdao. Therefore, when facing the competition of HSR, the Chinese airports may promote a higher number of LCCs flying on those routes. This could alleviate the financial loss caused by the HSR entry.
As shown in Section 7.3.1, the presence of LCCs poses challenges to the FSAs. Table A7.7 (Appendix A7) shows that passenger volumes and revenues decreased for FSAs (compared with the case without LCC presented in Chapter 6). This is explained by a transfer of air travellers to LCCs and HSR, as a result of increased supply of services at lower prices.

Furthermore, if both FSAs and LCCs decide to decrease their fares to respond to the competition brought by HSR, the airport benefits with a small increase in their revenues. Interestingly, on the shortest route, with a higher market share of LCC,
Qingdao, even the airport could get higher revenues from LCCs than in the case when HSR does not operate. The reason for this result is the modal switch from HSR to LCC, because of the competitive airfares. In this case, the presence of HSR ensures a “healthy” climate of modal competition with positive impact on the airport. Although the HSR generates negative effects for airlines, LCCs are potentially better equipped to respond to HSR and hence see value in adjusting their already reduced fares, as a measure to encourage more passengers and higher revenues to them.
8.1 Aims and Research Questions

With the growing trend towards airport commercialisation and privatisation, airports have experienced increasing pressure to become financially self-sufficient and less reliant on government support. Business-like operation has weakened the public utility function of airports and forced them to focus on increasing revenues and reducing costs. This research assists to better understand the revenue structure, acknowledging that many airport costs are fixed and ascribable to their assets, rather than to their operations.

Airports are multi-sided enterprises where numerous agents interact, and the revenues are affected by the inter-relationships between the parts: airport, airlines, passengers and government. They can respond quickly and effectively to the economic and social changes that affect demand and supply by identifying the approaches, partnerships and structures that are key to their revenue growth. Understanding the effects of the structure of relationships on airport revenues, as well as the implications of changing the airport revenue system, are fundamental to guiding and informing policy decisions for the airports, airlines and government, in different market situations.

This research was guided by the following Research Questions:

1. What is the long-term impact of price regulation on the revenue of airports with differing market power and what are the most important influencing factors in each price regulation regime?

2. What is the effect on the airport revenue of the competition between air and other transport modes (e.g. high speed rail) and how do airports and airlines work together to obtain mutual benefits?
(3) What is the impact of low-cost carriers on airport revenues?

Using a system dynamics (SD) approach, this research deconstructed the system of relationships among the multiple aspects of the airport into five modules: Demand, Traffic Volume, Airport Aeronautical Revenue, Non-Aeronautical Revenue and Capacity.

The use of causal loop and stock-and-flow diagrams, to set the links between components of airport revenues, is appropriate because of their transparent and easy manner, to hierarchically structure systems and allow interactions across space and time (Shepherd, 2014).

The SD structure built in this research is based on the two types of activities undertaken by an airport: i) the traditional, aeronautical operations; and ii) the non-aeronautical (commercial/concession) operations.

Revenues are generally collected from different sources: the aeronautical charges are paid by the airlines, and the non-aeronautical revenues are mainly obtained from passengers in the terminal. However, the final bearer of the airport charges is the passenger, who indirectly contributes to the aeronautical revenues through the airfares.

In general, lower airfares are expected to lead to higher passenger volumes. Airfares are affected by many factors, including market conditions, competition (with other airlines and other transport modes) and operating costs (of which the airport aeronautical charges may be a substantial part). The airport does not decide alone the value of the aeronautical charge; this is also regulated or monitored by the government. At some airports, the government may enforce an upper limit, or in many other cases, the government only watches and monitors the variation of the airport charges.

As indicated, the air transport industry as a whole must also deal with competition from other modes of transport including rail, car and bus. In recent years, high-speed rail (HSR) has gained a leading market share in the medium- to long-distance transport markets. This is because historically rail fares were lower than airfares; in addition to
their advantages of shorter inter-city journey times, comfort, convenience and a better environmental footprint.

However, the expansion of low-cost carriers (LCC) means that on some routes, prices for air transport are now similar to or below prices for rail transport, and this has the potential to reverse the market shares in favour of air transport. These operational and policy aspects have been detailed in this dissertation and evaluated in a series of SD models.

8.2 Contributions of This Research

This research provides methodological, practical and managerial contributions, detailed as follows:

- It provides a generic system dynamics (SD) simulation model to analyse the main factors influencing airport revenue and to evaluate their interrelated effects; this tool can be applied easily as a decision support system (DSS) to explore potential impacts of various regulation policies and competition; the model is built at two levels: high level and detailed/low level; capturing district long-term vs short- to medium-term airport decisions.

- It compares the airport revenue systems between airports with different market power, under different conditions; this is based on the data extracted from two case studies for middle-size airports, Perth, Western Australia and Nanjing, China, with similar scale of operation;

- It offers a guide to policy-making with respect to airport pricing and airport operation with a better understanding of the effect of multiple interactions on airport revenue and provides recommendations for combining measures
(including pricing, arrangements with airlines), which can optimise the airport’s revenues.

- It offers an expandable modelling structure, which creates the possibility to investigate various conditions – incorporating costs, maximising profits, accounting for passenger benefits and disadvantages.

### 8.2.1 Methodological Contributions

The SD model has been developed at two levels of detail: SD high-level (Chapters 4) and SD low-level (Chapters 5-7), and the aspects they analyse in detail are summarised in Table 8.1. The modelling shell is generic enough to be applied in any airport, changing only the model inputs.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>High-level model</th>
<th>Low-level model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model structure</td>
<td>Five modules (core structure): Demand; Traffic Volume; Airport Aeronautical Revenue; Airport Non-Aeronautical Revenue; Capacity.</td>
<td>Building on the core structure, a new Competition module was added.</td>
</tr>
<tr>
<td>Focal interactions examined</td>
<td>Regulation Market power</td>
<td>Competition: airlines with HSR. Competition: FSA with LCCs.</td>
</tr>
<tr>
<td>Case studies</td>
<td>Both Nanjing and Perth.</td>
<td>Nanjing and partially Perth.</td>
</tr>
</tbody>
</table>

The causal loops and stock-and-flow diagrams are useful tools in describing and communicating the key links in determining the airport revenues, highlighting reinforcing and balancing loops and showing changes in the system. Their simple representation is intuitive: loops indicate causal links; stocks are accumulations (depicted as rectangles - containers); and flows (depicted by pipes with valves controlling the rates) increase or decrease the stocks.
As indicated, the SD model also allows construction of additional components that can be attached to the core structure, for other purposes beyond the scope of this research (cost evaluation, passenger satisfaction). Considering the limited penetration of SD in (air) transport modelling (Shepherd, 2014), this research opens new directions of investigation and offers an application as a potential cross-validation tool for other modelling endeavours, as well as a useful learning environment. As a simulation approach, it represents a laboratory for experimenting with conditions for the whole set of agents interacting within the airport “space”, with the objective of understanding their revenue decisions. Its particular framework using stocks, flows (rates of change) and links, plus explicit feedback, enables the capture of the dynamics of how air travel demand, number of flights and revenues. (stocks) change over time, by estimating them according to the value of time slice (dt) for the flows. Consequently, SD models are suitable for investigating impacts of policies and strategy decisions, with the additional benefit of increasing system understanding and learning for those who participate in building, expanding and/or using the model (Macmillan et al., 2014).

8.2.2 Practical Contributions

The application to two distinct case studies and the comparative analysis of the results with the historical data provides evidence for the validity and credibility of a model that is versatile and can be tested in other conditions. Consistent with Sterman (2000, p. 858), this calibration and validation helps the analyst to learn more about the dynamic behaviour of the system and improve confidence in the findings.

Multiple stakeholders can use this SD model to assist policy-analysis at different levels: airports, government organisations, airlines and consultants.
Based on the “level 2 model”, investigating the interrelationships with the airlines, airports can simulate what-if scenarios to explore the impact of different policies like price-making on airport revenue and market responses (e.g. HSR competition). The model makes possible the investigation of the actions taken by airlines or other related agents, including government, as a permanent feedback to the airport’s decisions.

As SD is a top-down model, the modeller and/or user of the structure could investigate actions and effects at different levels of resolution. For example, the airport is able to investigate the differentiated impact of airport charges on different routes and airlines and make different price decisions accordingly, in order to optimise its revenues. These decisions may involve airline and route price discrimination under airport competition or agreements with other competing modes for multimodal bundles (e.g., train and air), based on the traffic the carriers bring to the airport. The airlines and the airport could also further deter the segmentation of the air travel market by purpose of travel and/or class and apply an airport charge based on a % of airfare, rather than a fixed value.

Government departments or policy makers can use the model to assess the impacts of different regulation regimes on airports at the aggregate level. Similarly, all stakeholders would be able to quantify the effects of joint decisions on passengers: airfare changes, quality and diversity of services offered within the airport premises, competition-induced modal changes and flexibility of travel solutions (e.g., train-plane combined travel).

Airlines could also apply this model structure to understand the impact of airport charge rate on the demand and their revenues, as well as the impact of HSR competition. By anticipating the changes in the inter-urban travel demand induced by HSR, airlines can take actions to minimise losses associated with modal shift. Similarly, full service airlines (FSA) could better adjust to the dynamic changes resulting from the emergence
of LCCs and decide in what conditions, and on which routes, they can maintain a good market share.

The flexible modular structure of the model allows for expansion by incorporating the structure of airline operation, thus further assisting airlines to make decisions based on the relationship between themselves, the airports, and government.

8.3 Summary of Findings

8.3.1 Regulation and the Role of Government

Based on two case studies, Perth and Nanjing airports, it is found that government regulation is essential when there is no competition with other modes: in both cases, the airport revenues are positively related to the airport charge rate. This means that lower charge rates cannot attract enough passengers (given the price elasticity of demand) and cannot considerably raise non-aeronautical revenues to the airports, to compensate for the loss of aeronautical revenues, if the passenger shopping behavior at terminal is unchanged (e.g. $ shopping/pax). Thus, in the absence of government regulation, the airport may charge higher rates to the airlines, in order to increase its revenues. In the case of Nanjing airport NKG, where price-cap regulation is in place, the airport prefers to apply the maximum charge rate in order to raise its revenues received from the airlines. Therefore, how the government decides the price-cap value is important. Currently, in China, the charge rate for different airports is set at three levels, depending on the airport’s traffic volume. However, different airports face different situations: even under the same traffic volume conditions, airports developing or undertaking new construction may find the airport charge inadequate for their operation, eroding their revenues. Therefore, such a price-cap regulation is unlikely to be an incentive for airports to approve new developments to increase their capacities. Conversely, in the case of Perth airport, how
the government assesses the airport charge rate and the effective negotiation between airport and airlines are key to the light-handed regulation, because the airport has the flexibility to adjust their airport charges upon new developments.

For airports without new substantial investments in assets, the single-till regulation favours the airlines and passengers, given the low charge rate compared with dual-till regulation; however, the regulation does not show any benefit for airports with high market power like Perth, because a lower charge rate cannot attract substantially more passengers to increase the non-aeronautical revenues of the airport and compensate for the losses in aeronautical revenues. On the other hand, if airports undertake substantial investments not necessarily leading to obvious aeronautical capacity expansion, and the increases in non-aeronautical revenues are limited, the charge rate of single-till regulation may be higher than for dual-till. Therefore, it is concluded that only if higher non-aeronautical revenues can be obtained from the same investment, the airport could successfully apply single-till regulation and bring greater benefits to the passengers.

8.3.2 Airport Revenues under Different Market Power Conditions

When considering the impact of changing the airport charges on the airport revenues, the results are similar for both Nanjing and Perth airports. Without competition and with identical charge rates, the total airport revenue drops with any decrease of the aeronautical charge rate, although the passenger volume increases. This effect holds irrespective of the airfare level. However, the reduction in airport revenues depends on the airfare. This result indicates that the airport does not have strong financial reasons to apply lower airport charges to the airlines, if there is no external competition. When the airfares are low (e.g., LCCs), the airports would be better off to refrain from substantial increases in airport charges. Similarly, the airport should apply wisely airport charge increases when the airfares are high. Therefore, in this case, government regulation is essential.
If price discrimination is allowed at the airport, for some routes with lower utilisation (SLF), higher charge rates may lead to a decrease in the airport revenue (e.g. airport revenues on routes Nanjing-Nanning and Nanjing-Xiamen decreased when the charge rate was increased by 60%, while in Perth only one route, Perth-Brisbane, displayed lower airport revenues, and only when the charge rate was increased by 80%). The mechanism is the following: an increase of the charge rate leads to passenger volume decrease and consequent reduction in number of flights (because of lower SLF). These reduced flight volumes further affect the airport revenue, through lower landing fees and fewer passengers, which are then translated into lower non-aeronautical revenues. The airport revenues are more sensitive to the levels of airport charges when the airfares are low and airport charges represent a relatively high proportion of the fare paid by the passengers. Therefore, the airports may consider charging different rates for different routes or airlines depending on their SLF. For routes with lower utilisation (SLF), charging higher rates is problematic; whereas for higher utilisation it may be feasible, provided that there is flexibility in the agreements with the airlines.

In terms of airline response to the change of airport charge rate, there are several differences between Nanjing and Perth airports. For Nanjing, the response of the airlines would be asymmetric with respect to the changes in airport charges. Airlines would be better off to fully pass on any decrease of airport charge rate to the passengers (by decreasing the airfares), while keeping the airfares unchanged when the airport increases the charge rate. This finding remains true irrespective of the airfare level, because maintaining passenger numbers is crucial for the airline revenues. If the airport charge increases, the airlines will incur a revenue loss. Nevertheless, as indicated, Chinese airports cannot increase their charges excessively, as a price-cap is applied to the aeronautical charge.
In the case of Perth airport, the airlines would benefit from passing an increase of airport charge rate to the passengers (by increasing the airfare), regardless of the airfare level. However, the airlines would pass any decrease of airport charge rate to the passengers only in the case of high airfares; for low airfares, it would be to the advantage of the airlines to keep the airfares unchanged when the airport decreases the charge rate.

The distinct findings between Perth and Nanjing airports may be explained by the different market power of these two airports and the magnitude of charges relative to airfares. Perth has higher market power and the ratio of airport charges to the average airfare is much lower than in Nanjing.

8.3.3 Competition with High Speed Rail (HSR) at Nanjing Airport

The main factors that commonly influence competition between air travel and HSR are: travel time by HSR, difference in fares and frequencies between HSR and airlines, perceived comfort and convenience (Dobruszkes, 2011; Yang and Zhang, 2012a). When the airport’s charge rate remains constant (and if the passengers’ shopping behaviour is assumed to be unchanged), the airport total revenue increases in proportion to the demand (number of travellers), which is affected by the airfare level and by the attractiveness of the HSR alternative.

The results show differentiated effects by origin-destination. After the HSR started operation on various routes from Nanjing, for some destinations (e.g. Wenzhou, Wuhan and Jinan), the airlines had to terminate their services in response to the competing HSR operation. This is because they experienced dramatic decreases in the passenger numbers (more than 70%), which affected both the airport and the airline revenues, no matter that maneuvers they adopted in response to the competition. Airlines could do
nothing but quit the market. These routes were more vulnerable, because of the shorter
distances they covered.

On other routes (e.g. Beijing, Changsha and Qingdao) where airlines still could survive, their early action of reducing the airfare was beneficial both for the airport and the airlines, as more passengers were attracted by the new fares. Consequently, the actions taken by airlines depend on the O-D routes, with the main determinants being travel time by HSR, differences in the fares, and differences in the service frequency between HSR and airlines.

The SD simulation results show that, regardless of when airlines take action by reducing the airfares, HSR has substantial negative impact on the number of passengers travelling by air, thus on the airport and airlines’ revenues. Such impact is greater on the airline revenues than on the airport revenues. On the other hand, if airlines only take action after HSR enters the market, they must change both airfare and frequency to compete with HSR and prevent substantial demand loss. Under the simulation conditions, it was found that a 20% decrease in airfares with adjusted frequency is a better solution for the airlines to remain active on a route, although this is associated with losing revenue and some market share. Lower airfares will bring down the airline revenues, but will benefit the airport, as the demand for air travel will not decrease. To prevent severe reductions in revenue, the airport could adopt the strategy of lower airport charges to enable airlines to reduce their airfares, especially when airfares are low, which is likely the case of short routes and/or services of LCCs.

With respect to operational decisions, reducing flight frequency may be an effective action for airlines to diminish costs and for the airport to cope with capacity constraints, but at the same time it negatively affects airport revenue. Moreover, lower
frequency may lead to lower demand in the longer-term, especially by those passengers very sensitive to time.

8.3.4 Competition by Low Cost Carriers

The competition of HSR in capturing new passengers on a route depends on the price differentials and service differentials. If airfares become cheaper than the HSR ticket prices, then the airlines will attract HSR passengers and the airfare reductions could bring higher revenues to the airport. It is unlikely that the airport would obtain additional revenues from the full-service airlines (FSA), which have higher airfares, even when the airport reduces its charges. In such a situation, LCCs become more important for the airport. The airport may prefer to offer lower airport charges to LCCs to encourage them to preserve lower airfares and higher frequencies. These measures are expected to attract more passengers, through which the airport could increase its revenues. From the point of view of LCCs, these aspects, together with their ability to compete with HSR, would give them a higher power or competitive edge to negotiate with the airport, in order to receive additional benefits. The scenario analysis indicates that if there are LCCs operating on a route, the airport is motivated to take different actions towards the different categories of airlines (FSAs vs LCCs), in order to get higher revenues.

8.3.5 Summary

Based on the final model simulations, it is concluded that government regulation is essential for an airport without competition from other modes, because the airport revenues are positively related to the airport charge rate. Although there is complementarity between aviation and non-aviation activities, the latter cannot counterbalance the loss of aeronautical revenues, if the passenger shopping behaviour at terminal is unchanged (e.g. $ shopping/pax). When government decides the price-cap for
an airport (e.g. Nanjing Airport) this regulation can hinder, rather than provide an incentive, to the airport to increase capacity through limited cost recovery mechanisms. On the other hand, under light-hand regulation (e.g. Perth Airport), the airport has the flexibility to adjust airport charges upon new developments; therefore, it is crucial for the government to assess whether new investments are necessary for an airport capacity increase. Negotiation between airport and airlines is also essential for “optimising” airport and airline revenues.

For airports, it is practical to apply different charge rates on different routes to optimise their revenues. Generally, the airports choose to apply higher charge rates when there is no competition. However, under competition with other modes, the airport could adopt different strategies of lowering charges, to enable airlines in their turn to reduce airfares. If there are LCCs in the market, the airport will differentiate between FSAs and LCCs, by offering lower airport charges to the LCCs to encourage them to diminish airfares and increase frequencies.

The model shows that HSR competition is likely to substantially erode the revenues of airports and airlines due to lower prices and higher frequency, especially on shorter distance routes. To compensate, airports and airlines are encouraged to work together to offer similar competitive services or distinct benefits for travellers (e.g., better connections, flexibility and reduced time on ground). Multimodal bundles could also be considered on some routes as potential strategies to secure demand.

8.4 Limitations and Further Research

As with any modelling effort, there are limitations associated with the work. The SD model presented here provides a basic platform to simulate a variety of scenarios, relying on data from different case studies and conditions, to set new parameter values in the
model. It is difficult to ascertain to what extent the case studies analysed in this thesis are representative for various types of airport operation.

However, the flexibility of the framework does allow for adaptations to local circumstances. To generate insights with larger applicability, fresh sets of conditions should be tested. This SD model represents the first step in developing and testing a modelling structure that can be expanded by considering a multifactorial analysis of relationships between airport, airlines and government in various geographical, socio-economic, and political contexts.

This model can be further developed to investigate the following areas:

1) Government policies – e.g. the impact of government taxes or fees on the airport revenue could be analysed within the high-level model.

2) The structure of airline operation – this could help airlines to assess a wider range of possible decisions based on the relationship with airports and government, and the detailed impacts of other airline actions on the airport revenue could be investigated (partnerships between airlines, ownership of passenger terminals.).

3) The competition with HSR module may be further developed – to incorporate factors like service quality, comfort and reliability, currently not included in the model. These “soft” variables could be investigated as determinants of service quality and passenger demand changes. Additionally, HSR price (here considered fixed) could be modified, to investigate effects on the market if HSR could provide flexible prices, similar to airlines.

4) Competition with other airports – this model details only competition with HSR, however the structure of competition with other airports could be added to the current competition module, by duplication. For example, Nanjing Airport is facing competition from other airports nearby, thus the HSR network could be
used by the airport and airlines flying to and from Nanjing to outperform the services of other airports. In this case, HSR would play a collaborator role with the airport, rather than be a competitor of the airlines.

5) Airline competition - is limited in this model, considering only the impact of LCC under competition with HSR. The competition between FSAs and LCCs involves more complex inter-relationships, relevant to the airport. For example, FSAs could link more terminal destinations to the hub network, when cooperating with HSR that has a city-to-city network. In this way, FSAs can take a more privileged position in their competition with LCCs. In the current inter-city travel market, competition is manifested not only between companies and organisations, but also between groups of companies and organisations. Such groups could be represented by airlines and airport, or airlines and HSR, even airport and HSR. Therefore, in the next step, this SD model could be expanded to simulate additional scenarios with more parameters and relations.

6) Differentiating between various classes of travellers – the current model assumes homogenous demand, without regard for the distinct travel motivations, preferences, benefits, values of time or price elasticities. With available data, it is feasible to duplicate the Demand module to account for multiple traveller categories.

8.5 Final Conclusion

This research developed a SD simulation model to explore the interactions governing airport operation, in order to identify how an airport can enhance its revenues under specific market structures, different airport-airline relationships and different regulatory schemes. Airports are viewed as platforms where airlines, passengers and companies interact; hence the network of relationships is what affects the total revenue of the airport.
The general conclusions suggest that government regulation is beneficial in the absence of airport competition and that the airport prefers to charge different rates for different routes and airlines in competition with other modes (e.g., HSR), although higher charges benefit the airport in most situations. Pliability in applying charging policies is essential and the ability to anticipate market changes gives the airport and airlines the possibility to prevent substantial losses. Finally, the existence of LCCs is very important for the airport when there is competition with other modes, therefore the airport may take different, more “protective” action towards LCCs, by imposing lower charges.

Although prior scholarly work has documented many of these relationships, to the best of knowledge of this author a holistic treatment of the airport revenue structure is yet to emerge. This is because econometric models may become intractable analytically and numerical analysis or simulation is called for.


CAAC (Civil Aviation Administration of China). 2010-2015. Statistic Data on Civil Aviation of China. CAAC Publication Ltd.


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STEER DAVIES GLEAVE. 2006. Air and Rail Competition and Complementarity. London: European Commission DG TREN.


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APPENDICES

A1 Program Coding iThink

High-level Model in Chapter 4

Sector 1 Demand

\[
\text{annual_airport_demand}(t) = \text{annual_airport_demand}(t - dt) + (\text{rate_of_demand_change}) \cdot dt
\]

INIT annual_airport_demand = 5,332,745

UNITS: passengers

DUCUMENTATION: The initial value is 5,332,745 for Perth and 6,969,100 for Nanjing.

rate_of_demand_change =

\[
\text{average_annual_increase_rate}\times\text{annual_airport_demand} + \text{annual_airport_demand}\times\text{airfare_effect} + \text{annual_airport_demand}\times\text{congestion_effect} + \text{competition_effect}\times\text{annual_airport_demand}
\]

UNITS: passengers/yr

average_airfare(t) = average_airfare(t - dt) + (airfare_change) \cdot dt

INIT average_airfare = 400

UNITS: Australian Dollars (AUD)

airfare_change =

\[
\text{aeronautical_charge_change_rate}\times\text{airline_pass_percentage} + \text{competition}
\]

UNITS: AUD/yr

airfare_effect = (airfare_change/average_airfare)/price_elasiticity

DUCUMENTATION: effect of airfare on demand

average_annual_increase_rate = 0.11

UNITS: /year

DUCUMENTATION: according the historical data, perth airport average demand growth rate =10% per year

price_elasiticity = -0.86

average_travel_time = 4

congestion_effect = congestion_change/average_travel_time*time_elasticity*(2/24)

DUCUMENTATION: demand elasiticity with respect to time

time_elasticity = -0.8

Sector 2 Airport Traffic Volume

\[
\text{annual_flights}(t) = \text{annual_flights}(t - dt) + (\text{flights_change_rate}) \times dt
\]

INIT annual_flights = 51650

UNITS: flights

DUCUMENTATION: initial data is 51,650/year for Perth and 64,591 for Nanjing.

flights_change_rate = if runway_utilization>=1 then 0 else (demand_impact_on_frequency)/frequency_adjust_time

UNITS: flights/yr

average_aircraft_size(t) = average_aircraft_size(t - dt) + (change_rate_of_size) \cdot dt

INIT average_aircraft_size = 130

UNITS: passengers/size
DUCUMENTATION: Calculated as an average statistic, annual total available seats/all movements are: Perth, in 2002, 130 pax/flight; Nanjing 110 pax/flight
change_rate_of_size = 0
UNITS: passengers/missions-yr
annual_pax = available_seats*real_load_factor
UNITS: passengers
DUCUMENTATION: if demand <= total available seats provided by airlines, airport pax=demand; if demand > total available seats, that means demand > airline capacity, pax<demand, means unsatisfied demand exists.
available_seats = annual_flights*average_aircraft_size
UNITS: passengers
average_flight_per_day = annual_flights/365
UNITS: flights/day
demand_impact_on_frequency = if SLF>1 then
uncompleted_demand/average_aircraft_size
else if SLF < slf_threshold then uncompleted_demand/average_aircraft_size
else 0
DUCUMENTATION: flights is changed by the demand. if desired slf>1, airline will increase the flight volume; if desired slf <0.5, airline providing and load factor<0.5, then airlines will decrease flight volume.
frequency_adjust_time = 0.25
UNITS: year
DUCUMENTATION: suppose airline will change frequency every three months
peak_hour_flight = average_flight_per_day*0.15
UNITS: flights/hour
DUCUMENTATION: perth airport, peak time midweek morning and afternoon, according the statistics, peak time in the morning is 6-8 am, in this period, departing flights account for above 80%. Here, I suppose peak hour flight volume (flights/hour) accounts for 15% of the total average daily flights.
real_load_factor = if SLF>1 then 1
else SLF
SLF = if available_seats=0 then 0
else annual_airport_demand/available_seats
slf_threshold = 0.5
DUCUMENTATION: Just assuming that different aircrafts have different breakeven points in terms of utilisation.
uncompleted_demand = annual_airport_demand-available_seats
UNITS: passengers
DUCUMENTATION: if >0, means demand > airlines capacity.

Sector 3 Aeronautical Revenue
aeronautical_charge_per_pax(t) = aeronautical_charge_per_pax(t - dt) +
(aeronautical_charge_change_rate) * dt
INIT aeronautical_charge_per_pax = 7.14
UNITS: Australian Dollars/passenger
DUCUMENTATION: For convenience, I use aeronautical revenue per pax to determine the aeronautical charge per pax.
aeronautical_charge_change_rate = if price_cap=0 then PULSE
(aeronautical_charge_adjust,adjust_time, adjust_time)
ELSE if price_gap>=0 then
if aeronautical_charge_adjust/adjust_time<=price_gap then
PULSE(aeronautical_charge_adjust,adjust_time, adjust_time)
else price_gap/adjust_time
else 0
UNITs: AUD/passenger-yr
DUCUMENTATION: PULSE(aeronautical_charge_adjust,adjust_time, adjust_time)
adjust_time = 1
UNITs: Year
DUCUMENTATION: how long the airport adjusts its charge rate
aeronatuiical_revenue_gap = annual_target_aeronatical_revenue-
annual_aeronatical_revenue
aeronautical_charge_adjust = aeronatuiical_revenue_gap/annual_pax
annual_aeronatical_revenue = annual_pax*aeronautical_charge_per_pax
UNITs: Australian Dollars (AUD)
annual_target_aerontical_revenue = if single_dual_till=0 then
noncurrent_assets_aero*target_rate_of_return_on_aero
else annual_target_revenue-total_non Aero_revenue
DUCUMENTATION: rate of return= revenue/noncurrent assets
price_gap = price_cap_value-aeronautical_charge_per_pax

Sector 4 Non-aero Revenue
spending_per_pax(t) = spending_per_pax(t - dt) + (shopping_change_rate) * dt
INIT spending_per_pax = 8
UNITs: Australian Dollars/passenger
DUCUMENTATION: shopping +ground transport; initial value for Nanjing is
RMB14.
shopping_change_rate = PULSE(1.9)*test
UNITs: australian dollars/passenger-yr
annual_trading_and_ground = spending_per_pax*annual_pax
UNITs: Australian Dollars (AUD)
percentage_of_two_non_revenue = 0.51
DUCUMENTATION: perth: (shopping +ground transport)/total nonaero
revenue=51%; Nanjing is 40%.
test = 1
total_non Aero_revenue = annual_trading_and_ground/percentage_of_two_non_revenue

Sector 5 Airport Capacity
runway__capacity_per_hour(t) = runway__capacity_per_hour(t - dt) +
(capacity_increase_rate) * dt
INIT runway__capacity_per_hour = 62
UNITs: flights/hour
DUCUMENTATION: perth, runway capacity departing per hour=38 flight per hour
and arriving 24 flight per hour.
capacity_increase_rate =
runway__capacity_per_hour*capacity_increase*capacity_increase_policy/deliverary_time
UNITs: flights/hour-yr
capacity_increase = 0
capacity_increase_policy = if runway_utilization>congestion_threshold then 1
else 0
DUCUMENTATION: if =1 , airport decides to increase capacity
congestion = LOOKUP(congestion_function,runway_utilization)
UNITs: hour/hour
DUCUMENTATION: congestion is defined as the waiting time per peak hour for each aircraft and congestion always happens at peak time.
congestion_change = congestion-HISTORY(congestion,time-1)
UNITS: hour/hour
DUCUMENTATION: the change of congestion time
congestion_threshold = 0.9
DUCUMENTATION: when the airport decides to increase capacity based on the runway utilization.
deliverary_time = 2
UNITS: year
DUCUMENTATION: how long the construction could be finished and capacity could be increased
runway_utiliztion = peak_hour_flight/(runway__capacity_per_hour)
DUCUMENTATION: departing flight capacity in peak time
capacity_utilization = GRAPH(time)
(1.00, 0.00), (2.00, 0.5), (3.00, 0.55), (4.00, 0.6), (5.00, 0.65), (6.00, 0.7), (7.00, 0.75), (8.00, 0.8), (9.00, 0.85), (10.0, 0.9), (11.0, 0.95), (12.0, 0.98), (13.0, 1.00)
congestion_function = GRAPH(capacity_utilization)
(0.00, 0.00), (0.1, 0.00), (0.2, 0.00), (0.3, 0.00), (0.4, 0.005), (0.5, 0.01), (0.6, 0.019), (0.7, 0.029), (0.8, 0.085), (0.9, 0.5), (1.00, 0.6)
UNITS:hour/per peak hour

Not in a Sector
noncurrent_assets_aero(t) = noncurrent_assets_aero(t - dt) + (investment_on_aero - depreciation) * dt
INIT noncurrent_assets_aero = 178,000,000
UNITS: Australian Dollars (AUD)
investment_on_aero = increase_rate+capacity_increase_rate
UNITS: AUD/yr
depreciation = noncurrent_assets_aero*depreciation_rate
UNITS: AUD/yr
total_noncurrent_assets(t) = total_noncurrent_assets(t - dt) +
(investment_on_total_airport - Flow_2) * dt
INIT total_noncurrent_assets = 414,000,000
INFLOWS:
investment_on_total_airport = total_increase_rate
Flow_2 = total_noncurrent_assets*depreciation_rate
aero_percentage = annual_aeronautical_revenue/total_airport_revenue
airline_pass_percentage = 1
annual_target_revenue = total_noncurrent_assets*rate_of_return
competition = 0
competition_effect = 0
DUCUMENTATION: included in price elasticity
Converter_1 = TIME
depreciation_rate = 0.02
investment_on_nonaero = investment_on_total_airport-investment_on_aero
price_cap = 0
price_cap_value = 10
rate_of_return = 0.228
single_dual_till = 0
DUCUMENTATION: if single-till =1, dual till=0, Perth and Nanjing both dual till
targe_rate_of_return_on_aero = 0.228

total_airport_revenue = total_non_aero_revenue+annual_aeronautical_revenue

increase_rate = GRAPH(Converter_1)

(1.00, 1.8e+007), (2.00, 3e+007), (3.00, 1.8e+007), (4.00, 1.6e+007), (5.00, 3.9e+007),
(6.00, 3.5e+007), (7.00, 5.8e+007), (8.00, 6e+007), (9.00, 1.5e+008), (10.0, 5e+007)
total_increase_rate = GRAPH(Converter_1)

(1.00, 3.1e+007), (2.00, -1.8e+007), (3.00, 1.4e+008), (4.00, 1e+008), (5.00, 9e+007),
(6.00, 8.7e+007), (7.00, 5.4e+007), (8.00, 5.2e+007), (9.00, 3.9e+008), (10.0, 5e+007)

\[ \text{Low-level Model in Chapter 5-7} \]

Aeronautical Revenue:
\[ \text{total_aeronautical_revenue}(t) = \text{total_aeronautical_revenue}(t - dt) + \]
(daily_aeronautical_revenue) * dt 

INIT total_aeronautical_revenue = 0 

daily_aeronautical_revenue = SUM(daily_route_aeronautical_revenue)

\[ \text{total_aeronautical_revenue_for_every_route}_{\&}_{\text{airline}}(route, airlines)(t) = \]
\[ \text{total_aeronautical_revenue_for_every_route}_{\&}_{\text{airline}}(route, airlines)(t - dt) + \]
(daily_aeronautical_revenue_for_every_route_{\&}_{airline}(route, airlines)) * dt 

INIT total_aeronautical_revenue_for_every_route_{\&}_{airline} = 0 

daily_aeronautical_revenue_for_every_route_{\&}_{airline}(route, airlines) =

landing_charge.daily_landing_charge_for_every_route_{\&}_{airline}+security_charge.daily_security_charge_for_every_route_{\&}_{airline}+terminal_charge.daily_terminal_charge_for_every_route_{\&}_{airline}

total_airline_aeronautical_revenue[airlines](t) =

total_airline_aeronautical_revenue[airlines](t - dt) + 
(daily__airline_aeronautical_revenue[airlines]) * dt 

INIT total_airline_aeronautical_revenue[airlines] = 0 

daily__airline_aeronautical_revenue[airlines] =

SUM(daily_aeronautical_revenue_for_every_route_{\&}_{airline}[*,airlines])

total_route_aeronautical_revenue[route](t) = total_route_aeronautical_revenue[route](t - dt) + (daily_route_aeronautical_revenue[route]) * dt 

INIT total_route_aeronautical_revenue[route] = 0 

daily_route_aeronautical_revenue[route] =

SUM(daily_aeronautical_revenue_for_every_route_{\&}_{airline}[route,*])

aeronautical_revenue_gap_per_pax =

total_airport_revenue_and_cost.target_aero_revenue_per_pax-
(aeronautical_revenue_per_pax)

aeronautical_revenue_per_pax = if traffic_volume.total_passengers_volume=0 then 0 else total_aeronautical_revenue/traffic_volume.total_passengers_volume 
aero_charge_rate_change = if (time MOD 360 =0) then 
aeronautical_revenue_gap_per_pax else 0 

DUCUMENTATION: aeronautical charge rate is adjusted once a year, at the end of 
every year.

airline_agreement[airline] = 0 

DUCUMENTATION: discount %. Initial value=0.

average_aeronautical_charge_per_pax[route, airlines] = if 
traffic_volume.total_passengers_for_every_route_{\&}_{airlines}=0 then 0
else

total_aeronautical_revenue_for_every_route_&_airline[route,airlines]/traffic_volume.total_passengers_for_every_route_&_airlines[route,airlines]
cap_controlled = 1

DOCUMENTATION: switch variable. light handed 0/1-australia mode; charge capped 0/1-china mode.

landing_fee_per_pax_change = aero_charge_rate_change*percent_landing_change
terminal_charge_per_pax_change =
aero_charge_rate_change*percent_terminal_change

Airline:

airline_daily_revenue_after_airport_charges[airlines](t) =
airline_daily_revenue_after_airport_charges[airlines](t - dt) +
(airline_daily_revenue[airlines] - airline_daily_cost[airlines]) * dt
INIT airline_daily_revenue_after_airport_charges[airlines] = 0

airline_daily_revenue[airlines] = SUM(airline_route_daily_revenue[*,airlines])

airline_daily_cost[airlines] = SUM(airline_route_daily_cost[*,airlines])
airline_route_daily_revenue_after_airport_charges[route, airlines](t) =
airline_route_daily_revenue_after_airport_charges[route, airlines](t - dt) +
(airline_route_daily_revenue[route, airlines] - airline_route_daily_cost[route, airlines]) * dt
INIT airline_route_daily_revenue_after_airport_charges[route, airlines] = 0

airline_route_daily_revenue[route, airlines] =
demand.airfare*traffic_volume.daily_passengers_for_every_route_&_airline[route,airlines]

airline_route_daily_cost[route, airlines] =
landing_charge.daily_landing_charge_for_every_route_&_airline[route,airlines]+security_charge.daily_security_charge_for_every_route_&_airline[route,airlines]+terminal_charge.daily_terminal_charge_for_every_route_&_airline[route,airlines]

UNITS: AUD or RMB/day

total_airline__revenue_after_airport_charges(t) =
total_airline__revenue_after_airport_charges(t - dt) + (total_airline_revenue - total_airline_cost) * dt
INIT total_airline__revenue_after_airport_charges = 0

total_airline_revenue = SUM(airline_daily_revenue)
total_airline_cost = SUM(airline_daily_cost)

UNITS: AUD or RMB

route_daily_revenue_for_airlines[route](t) = route_daily_revenue_for_airlines[route](t - dt) + (route_revenue_of_airlines[route] - route_cost_for_airlines[route]) * dt
INIT route_daily_revenue_for_airlines[route] = 0

route_revenue_of_airlines[route] = SUM(airline_route_daily_revenue[route,*])

route_cost_for_airlines[route] = SUM(airline_route_daily_cost[route,*])

airline_daily_profit = total_airline_revenue-total_airline_cost

airline_revenue_per_flight = if traffic_volume.airport_total_flights=0 then 0 else total_airline__revenue_after_airport_charges/traffic_volume.airport_total_flights

Demand:
demand[route, airlines](t) = demand[route, airlines](t - dt) + (daily_demand[route, airlines]) * dt
INIT demand[route, airlines] = 0

UNITS: passenger
daily_demand[route, airlines] = initial_daily_demand*(1+demand_delay[route]*Converter_4[airlines])
UNITS: passenger/day
DUCUMENTATION: daily demand(route, airline)
demand_change[route](t) = demand_change[route](t - dt) + (change_rate[route]) * dt
INIT demand_change[route] = 0
UNITS: passenger
DUCUMENTATION: demand change is based on the initial demand
INFLOWS:
change_rate[route] = airfare_effect*(1+demand_change)+
HSR_factor*(1+demand_change)
UNITS: passenger/day
airfare[route, airlines](t) = airfare[route, airlines](t - dt) + (airfare_change_rate[route, airlines] + airfare_change_by_airport_charge[route, airlines]) * dt
UNITS:AUD OR RMB
INIT airfare[route, airlines] = initial_airfare
DUCUMENTATION: initial airfare=standard airfare*initial aifare discount
airfare_change_rate[route, airlines] = standard_airfare*discount_rate_change
UNITS:AUD(RMB)/day
airfare_change_by_airport_charge[route, airlines] = percentage_airfare_change_pass*delay(total_airport_charge_change[route,airlines],airline_response_time_to_airport_charge)
airline_discount[route, airlines](t) = airline_discount[route, airlines](t - dt) + (discount_rate_change[route, airlines]) * dt
INIT airline_discount[route, airlines] = initial_airline_discount
UNITS: %
INFLOWS:
discount_rate_change[route, airlines] = if (airline_discount+effects_on_airfare)>1 and (airline_discount+effects_on_airfare)<0.1 then 0 else effects_on_airfare
UNITS: %/day
DUCUMENTATION: in nanjing:airfare=%* standard airfare( it is cap controled by the government). So, in the model, I change the % to revise the airfare, but the airline
discount must <=1
HSR_price[route](t) = HSR_price[route](t - dt) + (HSR_price_change_rate[route]) * dt
INIT HSR_price[route] = initial_HSR_price
HSR_price_change_rate[route] = HSR_price_change
route_demand[route](t) = route_demand[route](t - dt) + (daily_route_demand[route]) * dt
INIT route_demand[route] = 0
UNITS: passenger
daily_route_demand[route] = SUM(daily_demand[route, *])
UNITS: passenger/day
total_demand(t) = total_demand(t - dt) + (daily_total_demand) * dt
INIT total_demand = 0
UNITS: passenger
daily_total_demand = SUM(daily_route_demand)
UNITS: passenger/day
airfare_change[route] = if last_airfare=0 then 0 else (route_average_airfare-last_airfare)/last_airfare
UNITS: AUD(RMB)/passenger
airfare_change_matching_HSR[route, airlines] = 0
DUCUMENTATION: airlines change the airfare to match the price of HSR (changed discount)

airfare_change_time[route, airlines] = 60

DUCUMENTATION: when the airline change the airfare before HSR, or other reason

airfare_effect[route] = proportionate_change_in_airfare*Converter_7

DUCUMENTATION: proportionate_change_in_airfare*elasticity

airline_change_airfare[route, airline] = 0

DUCUMENTATION: airline change airfare before hsr enter, or because of other reason not HSR.increased or decreased %

airline_response_time[route, airlines] = 30

DUCUMENTATION: airline change airfare after HSR to beat their fare.

airline_response_time_to_airport_charge = 30

DUCUMENTATION: how long delay the airline changes airfare after the airport charge changed, suppose 30 days

average_spending_change_per_pax = mean(standard_airfare[*]*)*mean(total_airport_charge_change[*]*)

Converter_3[route, airlines] = traffic_volume.airline_market_share_per_route*airfare

Converter_4[airlines] = 1

Converter_5[route, airlines] = airline_discount*airline_change_airfare

Converter_6 = 0

DUCUMENTATION: for sensitivity

Converter_7[route] = elasticity+Converter_6

demand_delay[route] = SMTH1(demand_change,demand_delay_time)

demand_delay_time[route] = 20

DUCUMENTATION: time lag from the factor affecting the demand happens to the demand changes

demand_price_elasticity[route] = GRAPH(distance)

(700, -1.43), (1233, -1.16), (1767, -1.15), (2300, -1.14)

DUCUMENTATION: elasticity is different depending on the different airfare.

distance[route] = TIME

effects_on_airfare[route, airlines] =

PULSE(Converter_5,airfare_change_time,0)+effect_of_demand*price_self_adjusted+PULSE(airfare_change_matching_HSR,airline_response_time,0)*HSR[route]

effect_of_demand[route, airlines] = if traffic_volume.estimated_average_yearly_slf>1 then 0.01 else

if traffic_volume.estimated_average_yearly_slf<0.5 then -0.01 else 0

frequency_factor[route] = GRAPH(HSR_frequency)

(1.00, 0.8), (13.3, 1.10), (25.5, 1.30), (37.8, 1.40), (50.0, 1.50)

frequency_rate[route] = if traffic_volume.average_route_flights=0 then 0 else HSR_frequency*2/traffic_volume.average_route_flights

HSR[route] = 0

DUCUMENTATION: switch: if HSR exists in some route, =1, otherwise =0.Only consider HSR competition at different route, in a route, all the airlines will face HSR.

HSR_elasticity[route] = if frequency_rate>=5 then -time_factor*frequency_factor*1.5 ELSE if frequency_rate<1 then -time_factor*frequency_factor*0.8 else -time_factor*frequency_factor

HSR_enter_time[route] = 20

HSR_factor[route] = PULSE(HSR_elasticity,HSR_enter_time,0)*HSR

HSR_frequency[route] =(statistics data)

HSR_travel_time[route] = (statistics data)

initial_airfare[route, airlines] = standard_airfare*initial_airline_discount
initial_airline_discount[route, airline] = 0.4
UNITS:%
DUCUMENTATION: according the airport unit revenue, FSA RMB 0.70; LCC RMB 0.40.
initial_HSR_price[route] = (statistics data)
initial_daily_demand[route, airlines] =
traffic_volume.initial_seat_per_flight*traffic_volume.initial_average_slf*traffic_volume.initial_frequency*2*traffic_volume.slf_monthly_index
UNITS: passenger/day
DUCUMENTATION: two ways
last_airfare[route] = if time=0 then route_average_airfare
ELSE
HISTORY(route_average_airfare,time-1)
UNITS: RMB/passenger
lcc_enter[route] = 1
LCC_enter_time[route] = 20
UNITS: day
percentage_airfare_change_pass[route, airlines] = 0
DUCUMENTATION: how much the airline pass the increase or decrease of the landing fee to the passenger. If percentage=1, means fully pass to the pax through the airfare. Here, I suppose that, the airlines pass the landing fee change (cost or benefit) to the passenger directly through the tickets price
proportionate_change_in_airfare[route] = if route_average_airfare=0 then 0 ELSE
airfare_change +
(PULSE(relative_airfare_change, HSR_enter_time, 0)/route_average_airfare)*HSR
relative_airfare_change[route] = if HSR[route]=0 then 0 else
(route_average_airfare[route]-HSR_price[route])
route_average_airfare[route] = SUM(Converter_3[route,*])
UNITS: RMB/passenger
route_distance[route] = (statistics data)
UNITS: km
standard_airfare[route, airline] = (statistics data)
UNITS: RMB/passenger
DUCUMENTATION: in china, it is published airfare, normally airline could apply different discount based on this price.
time_factor[route] = GRAPH(HSR_travel_time)
(0.00, 1.00), (1.00, 0.8), (2.00, 0.6), (3.00, 0.3), (4.00, 0.2), (5.00, 0.1), (6.00, 0.1),
(7.00, 0.1), (8.00, 0.08), (9.00, 0.08), (10.0, 0.08), (11.0, 0.05), (12.0, 0.04), (13.0,
0.03), (14.0, 0.02), (15.0, 0.02)
total_airport_charge_change[route, airlines] =
(landing_charge.landing_rate_change[route, airlines]*landing_charge.average_landing
_charge_per_pax[route, airlines]+security_charge.security_rate_change[route, airlines]
+terminal_charge.terminal_charge_rate_change[route, airlines])
total airport charge=landing charge change+terminal charge change+security charge change
UNITS: RMB
Non-aeronautical Revenue:
total_non_aeronautical_revenue(t) = total_non_aeronautical_revenue(t - dt) +
(daily_non_aeronautical_revenue) * dt
INIT total_non_aeronautical_revenue = 0
UNITS: AUD OR RMB
daily_nonaeronautical_revenue = if fix_nonaero_in_same_case=0 then
daily__two_nonaeronautical_revenue/percentage_of_two_to_total
else
daily__two_nonaeronautical_revenue+endval(other_nonaeronautical_revenue)/360
total_nonaero_revenue_RA[route, airlines](t) = total_nonaero_revenue_RA[route, airlines](t - dt) + (daily_nonaero_revenue_RA[route, airlines]) * dt
UNITS: RMB/day
INIT total_nonaero_revenue_RA[route, airlines] = 0
daily_nonaero_revenue_RA[route, airlines] =
daily__two_nonaeronautical_revenue_RA/percentage_of_two_to_total
total_two_nonaeronautical_revenue(t) = total_two_nonaeronautical_revenue(t - dt) + (daily__two_nonaeronautical_revenue) * dt
INIT total_two_nonaeronautical_revenue = 0
daily__two_nonaeronautical_revenue =
ground_transport_revenue.daily_revenue_fr_ground_acess+trading_revenue.daily_trading_revenue
total_two_nonaero_revenue_RA[route, airlines](t) = total_two_nonaero_revenue_RA[route, airlines](t - dt) + (daily_two_nonaero_revenue_RA[route, airlines]) * dt
INIT total_two_nonaero_revenue_RA[route, airlines] = 0
INFLOWS:
daily_two_nonaero_revenue_RA[route, airlines] =
ground_transport_revenue.daily_revenue_fr_ground_RA+trading_revenue.daily_trading_revenue_for_every_route_&_airline
airport_unit_nonaeronautical_revenue = if traffic_volume.total_passengers_volume=0 THEN 0 ELSE
then 0 else
total_two_nonaeronautical_revenue/traffic_volume.total_passengers_volume
fix_nonaero_in_same_case = 0
DOCUMENTATION: only used in the case that I check the impact of the (ground transport+trading), and other nonaeronautical is fixed as the last round, in this case =1
other_nonaeronautical_revenue = total_nonaeronautical_revenue-
total_two_nonaeronautical_revenue
percentage_of_two_to_total = 1
DOCUMENTATION: the percentage of the two part non-aeronautical revenue relating to the pax (ground transport and trading). if only consider two nonaeronautical revenues, then 1.

Total Airport Revenue:
route_total_airport_revenue[route](t) = route_total_airport_revenue[route](t - dt) +
(route_daily_airport_revenue[route]) * dt
INIT route_total_airport_revenue[route] = 0
UNITS: AUD OR RMB
route_daily_airport_revenue[route] = SUM(daily_airport_revenue_RA[route,*])
total_airport_revenue_for_airlines[airlines](t) =
total_airport_revenue_for_airlines[airlines](t - dt) +
(daily_airport_revenue_for_airlines[airlines]) * dt
INIT total_airport_revenue_for_airlines[airlines] = 0
daily_airport_revenue_for_airlines[airlines] =
SUM(daily_airport_revenue_RA[*,airlines])
total_airport_revenue_RA[route, airlines](t) = total_airport_revenue_RA[route, airlines](t - dt) + (daily_airport_revenue_RA[route, airlines]) * dt
INIT total_airport_revenue_RA[route, airlines] = 0
daily_airport_revenue_RA[route, airlines] =
nonaeronautical_revenue.daily_nonaro_revenue_RA+aeronautical_revenue.daily_aero
nautical_revenue_for_every_route_&_airline
UNITS: AUD OR RMB/day
total_revenues(t) = total_revenues(t - dt) + (total_daily_revenues) * dt
INIT total_revenues = 0
total_daily_revenues = SUM(route_daily_airport_revenue)
UNITS: AUD OR RMB/day

Traffic Volume:
frequency_change[route, airlines](t) = frequency_change[route, airlines](t - dt) +
(frequency_change_rate[route, airlines]) * dt
INIT frequency_change[route, airlines] = 0
UNITS: flights/day
frequency_change_rate[route, airlines] = if
(Converter_3+SUM(frequency_change_condition)+
SUM(frequency_change))+SUM(lcc_frequency) >runway_daily_capacity
then 0 else
frequency_change_condition+ pulse
(lcc_frequency,demand.LCC_enter_time[route]*Converter_6[airlines],0)*demand.lcc_e
nter[route]*Converter_6[airlines]
UNITS: flights/day
DUCUMENTATION: if there is new enter, then new airline enter is 1, so input the
new frequency for the new airline and new route.
aircraft[route, airlines](t) = aircraft[route, airlines](t - dt) + (aircraft_change[route,
airlines]) * dt
INIT aircraft[route, airlines] = initial_aircraft
airline_flights[airlines](t) = airline_flights[airlines](t - dt) +
(airline_daily_flights[airlines]) * dt
INIT airline_flights[airlines] = 0
UNITS: flight
airline_daily_flights[airlines] =
SUM(daily_flights_for_every_route_&_airline[*,airlines])
UNITS: flight/day
airline_passengers[airlines](t) = airline_passengers[airlines](t - dt) +
(airline_daily_passengers[airlines]) * dt
INIT airline_passengers[airlines] = 0
UNITS: passennger
airline_daily_passengers[airlines] =
SUM(daily_passengers_for_every_route_&_airline[*,airlines])
UNITS: passennger/day
airport_total_flights(t) = airport_total_flights(t - dt) + (airport_daily_flights) * dt
INIT airport_total_flights = 0
UNITS: flight
airport_daily_flights = SUM(airline_daily_flights)
UNITS: flight/day
route_availbe_seat[route](t) = route_availbe_seat[route](t - dt) +
(route_daily_availabe_seat[route]) * dt
INIT route_availbe_seat[route] = 0
UNITS: passennger
route_daily_availabe_seat[route] =
SUM(daily_seat_available_for_route_and_airline[route, *])
route_flights[route](t) = route_flights[route](t - dt) + (route_daily_flights[route]) * dt
INIT route_flights[route] = 0

route_daily_flights[route] = SUM(daily_flights_for_every_route_&_airline[route,*])

route_passengers[route](t) = route_passengers[route](t - dt) + (route_daily_passengers[route]) * dt
INIT route_passengers[route] = 0

route_daily_passengers[route] = SUM(daily_passengers_for_every_route_&_airline[route,*])

seat_per_flight[route, airlines](t) = seat_per_flight[route, airlines](t - dt) + (seat_change[route, airlines]) * dt
INIT seat_per_flight[route, airlines] = initial_seat_per_flight

seat_change[route, airlines] = target_seat_per_flight - seat_per_flight

total_flights_for_every_route_&_airline[route, airlines](t) = total_flights_for_every_route_&_airline[route, airlines](t - dt) + (daily_flights_for_every_route_&_airline[route, airlines]) * dt
INIT total_flights_for_every_route_&_airline[route, airlines] = 0

total_passengers_for_every_route_&_airlines[route, airlines](t) = total_passengers_for_every_route_&_airlines[route, airlines](t - dt) + (daily_passengers_for_every_route_&_airline[route, airlines]) * dt
INIT total_passengers_for_every_route_&_airlines[route, airlines] = 0

INFLOWS:
daily_passengers = SUM(route_daily_passengers)

UNITS: passenger/day

DUCUMENTATION: flights volume for each route
DUCUMENTATION: how many scheduled flights per day for one airline one route
DUCUMENTATION: initial demand=0 means new route
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total_seat_available[route, airlines](t) = total_seat_available[route, airlines](t - dt) +
(daily_seat_available_for_route_and_airline[route, airlines]) * dt
INIT total_seat_available[route, airlines] = 0
UNITS: passenger
daily_seat_available_for_route_and_airline[route, airlines] = frequency*seat_per_flight
UNITS: passenger/day
DUCUMENTATION: how many seat can be provided every day
aircraft_change_policy[route, airlines] = 0
DUCUMENTATION: if airline change aircrafts size, yes=1, no=0
aircraft_type = GRAPH(TIME)
(1.00, 0.00), (36.9, 0.00), (72.8, 0.00), (109, 0.00), (145, 0.00), (181, 0.00), (216, 0.00),
(252, 0.00), (288, 0.00), (324, 0.00), (360, 0.00)
airline_market_share_per_route[route, airlines] =
airline_market__capacity_share*slf_impact
airline_market__capacity_share[route, airlines] = if
SUM(daily_seat_available_for_route_and_airline[route,]*)=0 then 0
else
daily_seat_available_for_route_and_airline[route,]*SUM(daily_seat_available_for_route_and_airline[route,]*)
average_route_flights[route] = (SMTH1(route_daily_flights,7))
UNITS: flight/day
competitor’s_frequency_factor[route, airlines] = GRAPH(0)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00,
0.00)
DUCUMENTATION: this competitor's frequency factor is considered in the condition
that there's a competitor in the same route or similar route, then airline will think of
increasing or decreasing the frequency to beat the competitor. So, here the factor stands
for the incremental value.
Converter_2 = SUM(initial_frequency)
Converter_3 = MAX(Converter_2, HISTORY(Converter_2,time -1))
Converter_6[airlines] = 1
Converter_7[route, airlines] = airline_market__capacity_share*slf_lcc_to_fsa
daily_slf[route, airlines] = if daily_seat_available_for_route_and_airline=0 then 0 else
daily_passengers_for_every_route_&_airline/daily_seat_available_for_route_and_airline
day_of_week = counter (0,6)
DUCUMENTATION: dt=per day, divide time into cycle of every week
estimated_average_yearly_slf[route, airlines] = SMTH1(Noname_1,30)
DUCUMENTATION: average slf
frequency[route, airlines] = if (initial_frequency+frequency_change)<0 then 0 else
initial_frequency*2+frequency_change
UNITS: flights/day
frequency_change_condition[route, airlines] = pulse
(competitor's_frequency_factor,frequency_change_time_2,0)
+slf_factor*frequency_change_time
frequency_change_time[route, airlines] = if slf_factor=1 or slf_factor=-1 then 1 else 0
frequency_change_time_2[route, airlines] = 40
frequency_policy[route, airlines] = 0
DUCUMENTATION: if airline change frequency, yes=1, no=0
initial_aircraft[route, airline] = 0 (aircraft type code)
DUCUMENTATION: aircraft type for every route and airline, suppose one type
aircraft is used in one route and one airline for all days. Type code: 0-22
initial_average_slf[route, airline] = (statistic data)
DUCUMENTATION: last year's average slf for this route. E.g.
initial_average_slf[Shenyang, PN] = 0.831.
initial_frequency[route, airline] = GRAPH(day_of_week)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00)
UNITS: flights/day
DUCUMENTATION: according to the airport flight schedule, flights per day for all
route airlines. Two dimensions: route and airline
initial_seat_per_flight[route, airlines] =
lookup(seat_capacity, initial_aircraft[route, airlines])
UNITS: pax/flight
DUCUMENTATION: the seat capacity for specific aircraft
lcc_frequency[route, airline] = 0
lcc_market_share[route] =
airline_market_share_per_route[ROUTE, KN]+airline_market_share_per_route[ROUTE, PN]+airline_market_share_per_route[ROUTE, AQ]+airline_market_share_per_route[ROUTE, A9C]
month_of_year = ((INT ( (time - 1) /30)) MOD 12)+1
mtow = GRAPH(aircraft_type)
(0.00, 0.00), (1.00, 56.5), (2.00, 70.8), (3.00, 62.9), (4.00, 70.8), (5.00, 79.2), (6.00, 263), (7.00, 352), (8.00, 397), (9.00, 66.0), (10.0, 75.5), (11.0, 73.5), (12.0, 93.0), (13.0, 240), (14.0, 240), (15.0, 575), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 45.0), (21.0, 33.0), (22.0, 47.8), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00)
DUCUMENTATION: mtow: maximum take off weight( ton). Graphical function:
aircraft type- mtow
Noname_1[route, airlines] = daily_slf/slff_monthly_index
real_daily_slf[route, airlines] = if daily_seat_available_for_route_and_airline=0 then 0
else
daily_passegrs_for_every_route & airline/daily_seat_available_for_route_and_airline
route_airline_average_pax_per_flight[route, airlines] = if
total_flights_for_every_route & airline[route,airlines]=0 then 0
else
total_passengers_for_every_route & airlines[route,airlines]/total_flights_for_every_route & airline[route,airlines]
UNITS: passenger/flight
route_slf[route] = IF route_daily_available_seat=0 then 0
else
demand.daily_route_demand/route_daily_available_seat
runway_daily_capacity = 200
seat_capacity = GRAPH(aircraft_type)
(0.00, 0.00), (1.00, 124), (2.00, 126), (3.00, 158), (4.00, 163), (5.00, 162), (6.00, 360),
(7.00, 386), (8.00, 466), (9.00, 107), (10.0, 124), (11.0, 150), (12.0, 185), (13.0, 246),
(14.0, 300), (15.0, 544), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 50.0),
(21.0, 50.0), (22.0, 90.0), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00)
DUCUMENTATION: maximum seat for different aircraft type
slf_factor[route, airlines] = if (estimated_average_yearly_slf>0.9 and daily_slf>1)
then 1 *frequency_policy
else( if (estimated_average_yearly_slf<0.7 and daily_slf<0.7 and daily_slf>0 ) then (-1*frequency_policy)
else 0)
DUCUMENTATION: policy is different: lcc 70%-99%; fsa 60%-90%
slf_impact[route, airlines] = if SUM(Converter_7[route,*])=0 then 0
else 1/SUM(Converter_7[route,*])*slf_lcc_to_fsa
slf_lcc_to_fsa[route, airlines] = if \( \text{MAX}(\text{demand.airfare}[\text{route},*]) / \text{demand.airfare} = 1 \)

\( \text{THEN } 1 \)

else

\( \text{else } 1.16 * (\text{MAX}(\text{demand.airfare}[\text{route},*]) / \text{demand.airfare}) * 4 / 7 \)

\( \text{if } \text{MAX}(\text{demand.airfare}[\text{route},*]) / \text{demand.airfare} = 1 \text{ THEN slf_rate_lcc_to_fsa, else slf_rate_lcc_to_fsa*MAX(\text{demand.airfare}[\text{route},*]) / \text{demand.airfare}) * 4 / 7 \)

slf_monthly_index = \( \text{GRAPH(month_of_year)} \)

\( (1.00, 0.896), (2.00, 0.875), (3.00, 0.956), (4.00, 1.01), (5.00, 0.969), (6.00, 0.974), (7.00, 1.17), (8.00, 1.19), (9.00, 1.02), (10.0, 1.09), (11.0, 0.943), (12.0, 0.901) \)

target_seat_per_flight[route, airlines] = \( \text{lookup(\text{seat_capacity}, \text{aircraft})} \)

_UINTS: \text{passenger/flight}

Aeronautical Revenue: Landing Charge (the Structures of Terminal and Security Charge Are Similar)

\( \text{landing_charge_rate_discount}[\text{route, airlines}][t] = \text{landing_charge_rate_discount}[\text{route, airlines}][t - \text{dt} + (\text{landing_charge_rate_change_rate}[\text{route, airlines}]) * \text{dt} \)

\( \text{INIT } \text{landing_charge_rate_discount}[\text{route, airlines}] = 1 \)

_UINTS: %

\( \text{DUCUMENTATION: the discount rate for every route. The initial value is 1, means at first, the standard rate is applied to all route} \)

\( \text{landing_charge_rate_change_rate}[\text{route, airlines}] = \text{IF } \text{landing_charge_rate_discount} = 0 \text{ THEN 0 ELSE } \)

\( \text{if aeronautical_revenue.cap_controlled} = 1 \text{ THEN } \)

\( \text{if ( landing_charge_rate_discount} + (\text{pulse(\text{route_landing_discount}, \text{time_Converter_1}, 0}) + \text{PULSE(\text{airline_discount}, \text{effect_Converter_1}, 0))) * \text{standard_landing_charge_rate} > (\text{landing_charge_cap}) \text{ then 0} \)

\( \text{else ( pulse(\text{route_landing_discount}, \text{time_Converter_1}, 0}) + \text{PULSE(\text{airline_discount}, \text{effect_Converter_1}, 0))) } \)

\( \text{else ( pulse(\text{route_landing_discount}, \text{time_Converter_1}, 0}) + \text{PULSE(\text{airline_discount}, \text{effect_Converter_1}, 0))) } \)

\( \text{DUCUMENTATION: changed percentage: increase=+, decrease=-. e.g 0.1=increase 10%, -0.1= decrease 10%} \)

\( \text{standard_landing_charge_total_change}[\text{route, airlines}][t] = \text{standard_landing_charge_total_change}[\text{route, airlines}][t - \text{dt}] + (\text{standard_landing_change_rate}[\text{route, airlines}]) * \text{dt} \)

\( \text{INIT } \text{standard_landing_charge_total_change}[\text{route, airlines}] = 1 \)

_UINTS: %

\( \text{DUCUMENTATION: present the standard landing charge rate change with changing %} \)

\( \text{standard_landing_charge_rate}[\text{route, airlines}] = \text{if aeronautical_revenue.cap_controlled} = 1 \)

\( \text{then if} \)

\( \text{standard_landing_charge_rate} * (1 + \text{landing_fee_changed__percentage}) > \text{landing_charge_cap} \text{ then 0} \)

\( \text{else landing_fee_changed__percentage} \)

\( \text{else landing_fee_changed__percentage} \)

\( \text{total_airline_landing_charge}[\text{airlines}][t] = \text{total_airline_landing_charge}[\text{airlines}][t - \text{dt}] + (\text{daily_airline_landing_charge}[\text{airlines}]) * \text{dt} \)

\( \text{INIT } \text{total_airline_landing_charge}[\text{airlines}] = 0 \)

\( \text{daily_airline_landing_charge}[\text{airlines}] = \text{SUM(daily_landing_charge_for_every_route_&_airline[*],airlines)} \)
total_landing_charges(t) = total_landing_charges(t - dt) + (daily_landing_charge) * dt
INIT total_landing_charges = 0
daily_landing_charge = SUM(daily_route_landing_charge)
total_route_landing_charge[route](t) = total_route_landing_charge[route](t - dt) + (daily_route_landing_charge[route]) * dt
INIT total_route_landing_charge[route] = 0
daily_route_landing_charge[route] = SUM(daily_landing_charge_for_every_route_&_airline[route, *])
total__landing_charge_for_every_route_&_airline[route, airlines](t) = total__landing_charge_for_every_route_&_airline[route, airlines](t - dt) + (daily_landing_charge_for_every_route_&_airline[route, airlines]) * dt
INIT total__landing_charge_for_every_route_&_airline[route, airlines] = 0

DOCUMENTATION: the accumulated landing charge for one airline one route
daily_landing_charge_for_every_route_&_airline[route, airlines] = ((passenger_standard*traffic_volume.daily_passengrs_for_every_route_&_airline[route, airlines]+MTOW_standard*traffic_volume.daily_flights_for_every_route_&_airline[route, airlines])*route_airline_landing_charge_rate)/2
DOCUMENTATION: two methods to compute the landing fee: charge $ per pax (pax standard =1); charge $ per flight (MTOW standard =1)
UNITS: AUD OR RMB/pax
airline_discount[route, airlines] =
aeronautical_revenue.airline_agreement[airlines]*Noname_1
average_landing_charge_per_pax[route, airlines] = if traffic_volume.total_passengers_for_every_route_&_airlines[route, airlines]=0 then 0 else(total__landing_charge_for_every_route_&_airline[route, airlines]/traffic_volume.total_passengers_for_every_route_&_airlines[route, airlines])
change_time_1[route] = 30
UNITS: day
DOCUMENTATION: when the charge rate change?
competition_factor_1[route] = 0
effect_Converter_1[route, airlines] = effect_time_1[airlines]*Noname_1
effect_time_1[airlines] = 30
DOCUMENTATION: when the agreement takes effective.
flight_mtow[route, airlines] = lookup(traffic_volume.mtow, traffic_volume.aircraft[route, airlines])
UNITS: kg
DOCUMENTATION: aircraft type---MTOW
flight__initial_standard_landing_charge[route, airlines] = lookup(initial_standard_landing_charge_in_mtow, flight_mtow[route, airlines])
UNITS: RMB/flight
DOCUMENTATION: mtow---- landing charge , based on the calculation criteria
initial_standard_landing_charge_in_mtow = GRAPH(x)
(0.00, 0.00), (1.00, 250), (25.0, 250), (26.0, 700), (50.0, 700), (51.0, 1174), (100, 2350), (101, 2376), (200, 4950), (201, 5133), (300, 8400), (600, 18300)
UNITS: RMB/kg
DOCUMENTATION: calculate the landing fee based on MTOW in NANJING.
MTOW is converted to landing fee by standard landing charge in MTOW.
initial_standard_landing_charge_rate[route, airlines] =
(MTOW_standard*flight__initial_standard_landing_charge+passenger_standard*initial__standard__landing_charge_rate_per_pax)
DOCUMENTATION: if mtow=1 then standard landing fee=$/flight; if passenger standard=1, standard landing fee=$/pax

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initial_standard_landing_charge_rate_per_pax = 4.2
DUCUMENTATION: this is the standard rate the airport published, used in AUD per pax in Perth.
landing_charge_cap[route, airlines] = initial_standard_landing_charge_rate
landing_fee_changed__percentage = if landing_fee_per_pax=0 then 0
else aeronautical_revenue.landing_fee_per_pax_change/landing_fee_per_pax
landing_fee_per_pax = if traffic_volume.total_passengers_volume=0 then 0
else (total_landing_charges/traffic_volume.total_passengers_volume)*2
landing__rate_change[route, airlines] = 
landing_charge_rate_change_rate+standard_landing_change_rate
DUCUMENTATION: the value changed in the charge rate, not the changed %
mtow_category = GRAPH(x)
(1.00, 0.00), (2.00, 1.00), (3.00, 25.0), (4.00, 26.0), (5.00, 50.0), (6.00, 51.0), (7.00, 100), (8.00, 101), (9.00, 200), (10.0, 201), (11.0, 300), (12.0, 600)
MTOW_standard = 1
DUCUMENTATION: if the landing fee is charged by MTOW, The MTOW standard is set 1, otherwise, it is set 0.
Noname_1[route, airlines] = 1
passenger_standard = 0
DUCUMENTATION: if the landing fee is charged by per passenger then passenger standard is set 1, if the landing fee is charged by MTOW, then it is set 0
route_airline_landing_charge_rate[route, airlines] = 
landing_charge_rate_discount*standard_landing_charge_rate
DUCUMENTATION: this is the real charge rate charged to any route or airline
route_landing_discount[route, airlines] = competition_factor_1[route]*Noname_1
standard_landing_charge_rate[route, airlines] = 
standard_landing_charge_total_change*initial_standard_landing_charge_rate
DUCUMENTATION: this standard charge rate is the rate published by the airport officially. It is basically decided by the airport cost and regulation(cap, single/dual-till).
time_Converter_1[route, airlines] = change_time_1[route]*Noname_1
x = time

Non-aeronautical Revenue: Ground Transport Revenue
car_parking_market_share(t) = car_parking_market_share(t - dt) +
(car_parking_share_change) * dt
INIT car_parking_market_share = car_paking_market_percentage
UNITS:%
car_parking_share_change = SUM(car_parking_share_change_in_all_competition)
other_mode_market_share[other_ground_transport_mode](t) = 
other_mode_market_share[other_ground_transport_mode](t - dt) +
(other_mode_share_change[other_ground_transport_mode]) * dt
INIT other_mode_market_share[other_ground_transport_mode] = 
other_mode_market_percentage
other_mode_share_change[other_ground_transport_mode] =
pulse(competition_with_other_modes[other_ground_transport_mode],
change_time[other_ground_transport_mode])
revenue_from_car_hire_RA[route, airlines](t) = revenue_from_car_hire_RA[route,
airlines](t - dt) + (daily_revenue_fr_CH_RA[route, airlines]) * dt
UNITS: %
INIT revenue_from_car_hire_RA[route, airlines] = 0
UNITS: AUD OR RMB
daily_revenue_fr_CH_RA[route, airlines] =
other_mode_market_share[car_hiring]*revenue_per_customer*traffic_volume.daily_passengers_for_every_route&_airline

revenue_from_public_RA[route, airlines](t) = revenue_from_public_RA[route, airlines](t - dt) + (daily_revenue_fr_public_RA[route, airlines]) * dt
INIT revenue_from_public_RA[route, airlines] = 0
daily_revenue_fr_public_RA[route, airlines] =
traffic_volume.daily_passengers_for_every_route&_airline*charge_rate_for_public*other_mode_market_share[public_transport]
revenue_from_taxi_and_limo_RA[route, airlines](t) =
revenue_from_taxi_and_limo_RA[route, airlines](t - dt) +
(daily_revenue_fr_taxi_RA[route, airlines]) * dt
INIT revenue_from_taxi_and_limo_RA[route, airlines] = 0

UNITS: AUD OR RMB
daily_revenue_fr_taxi_RA[route, airlines] =
other_mode_market_share[taxi_and_limo]*traffic_volume.daily_passengers_for_every_route&_airline*charge_rate_for_taxi_and_limo
total_LT_parking_revenue_RA[route, airlines](t) =
total_LT_parking_revenue_RA[route, airlines](t - dt) +
(daily_LT_parking_revenue_RA[route, airlines]) * dt
INIT total_LT_parking_revenue_RA[route, airlines] = 0
DUCOMATICATION: long term parking revenue for every route and airline
daily_LT_parking_revenue_RA[route, airlines] =
traffic_volume.daily_passengers_for_every_route&_airline*average_spending_per_pax_in_LT*(percentage_of_LT/100)*car_parking_market_share
total_parking_revenue_every_route_airlines[route, airlines](t) =
total_parking_revenue_every_route_airlines[route, airlines](t - dt) +
(daily_parking_revenue_RA[route, airlines]) * dt
INIT total_parking_revenue_every_route_airlines[route, airlines] = 0
daily_parking_revenue_RA[route, airlines] =
daily_ST_parking_revnue_RA+daily_LT_parking_revenue_RA
total_parking_revenue_for_route[route](t) = total_parking_revenue_for_route[route](t - dt) + (daily_revenue_fr_ground_RA[route, airlines]) * dt
INIT total_parking_revenue_for_route[route] = 0
UNITS: AUD OR RMB
daily_route__revenue_fr_gound[route] = SUM(daily_revenue_fr_ground_RA[route, *])
total_revenue_from_ground_acess(t) = total_revenue_from_ground_acess(t - dt) +
(daily_revenue_fr_ground_acess) * dt
INIT total_revenue_from_ground_acess = 0
UNITS: AUD OR RMB
daily_revenue_fr_ground_acess = SUM(daily_route__revenue_fr_gound[*])
total_revenue_fr_ground_RA[route, airlines](t) = total_revenue_fr_ground_RA[route, airlines](t - dt) + (daily_revenue_fr_ground_RA[route, airlines]) * dt
INIT total_revenue_fr_ground_RA[route, airlines] = 0
daily_revenue_fr_ground_RA[route, airlines] =
daily_parking_revenue_RA+daily_route__revenue_fr_gound[route] RA+daily_revenue_fr_CH_RA+daily_revenue_fr_public_RA

UNITS: AUD OR RMB/day
total_ST_parking_revenue_RA[route, airlines](t) =
total_ST_parking_revenue_RA[route, airlines](t - dt) +
(daily_parking_revenue_RA[route, airlines]) * dt
INIT total_ST_parking_revenue_RA[route, airlines] = 0
DUCUMENTATION: short term parking revenue for every route and airline
\[
daily\_ST\_parking\_revenue\_RA[route, airlines] = \\
traffic\_volume.daily\_passengers\_for\_every\_route\_&\_airline*average\_spending\_per\_pax\_in\_ST*(percentage\_of\_ST/100)*car\_parking\_market\_share \\
\text{average\_spending\_per\_pax\_in\_LT = NORMAL}(52,12) \\
\text{UNITS: AUD OR RMB/pax} \\
\text{average\_spending\_per\_pax\_in\_ST = NORMAL}(8.3, 1.7) \\
\text{car\_hire\_charge\_rate\_change = 1} \\
\text{DUCUMENTATION: airport charge car hire company \%+ fixed rental, according the car rental price, here, I set this rate is airport concession recovery fee showed in the price. In 2011, for Perth, ACRF=14\% (I set ACRF change rate to examine the effect on the customer spending, also the revenue per customer).} \\
\text{car\_parking\_market\_percentage = 0.22} \\
\text{UNITS: \%} \\
\text{DUCUMENTATION: perth 0.33, nanjing 0.22} \\
\text{car\_parking\_share\_change\_in\_all\_competition[other\_ground\_transport\_mode] = pulse(competition\_with\_other\_modes[other\_ground\_transport\_mode], change\_time[other\_ground\_transport\_mode],0)} \\
\text{change\_time[other\_ground\_transport\_mode] = 0} \\
\text{charge\_rate\_for\_car\_hiring = 17} \\
\text{charge\_rate\_for\_public = 25} \\
\text{DUCUMENTATION: Perth, public transport e.g. bus and coach are operated by other company, and the airport dosen’t charge any fee for them. Nanjing: the airport operates the coach, charge 20 per pax,, and there are other companies can provide the same service as long as they can get the permit from the government. The airport dosen’t charge any fee for these companies. So here, I just consider the revenue from the airport own} \\
\text{charge\_rate\_for\_taxi\_and\_limo = 0} \\
\text{DUCUMENTATION: 2011,airport charges $2 for per taxi pick up only, drop off for free, and charges $2.2 for limo per exit short term parking} \\
\text{competition\_with\_other\_modes[other\_ground\_transport\_mode] = 0} \\
\text{DUCUMENTATION: the value is \%, means the change of the car hire market share, + stand for increase, - decrease, but to car parking, the situation is oppistie. + means decrease.} \\
\text{other\_mode\_market\_percentage[car\_hiring] = 0} \\
\text{other\_mode\_market\_percentage[taxi\_and\_limo] = 0} \\
\text{UNITS: \%} \\
\text{other\_mode\_market\_percentage[public\_transport] = 0.19} \\
\text{percentage\_of\_LT = 0} \\
\text{percentage\_of\_ST = 100} \\
\text{revenue\_per\_customer = car\_hire\_charge\_rate\_change*charge\_rate\_for\_car\_hiring} \\
\text{Non-aeronautical Revenue: Trading Revenue} \\
\text{total\_airline\_trading\_revenue[airlines](t) = total\_airline\_trading\_revenue[airlines](t - dt) + (daily\_airline\_trading\_revenue[airlines]) * dt} \\
\text{INIT total\_airline\_trading\_revenue[airlines] = 0} \\
\text{UNITS: AUD OR RMB} \\
\text{daily\_airline\_trading\_revenue[airlines] = SUM(daily\_trading\_revenue\_for\_every\_route\_&\_airline[*\_airlines])} \\
\text{total\_route\_trading\_revenue[route](t) = total\_route\_trading\_revenue[route](t - dt) + (daily\_route\_trading\_revenue[route]) * dt} \\
\text{UNITS: AUC/RMB/day}
INIT total_route_trading_revenue[route] = 0
daily_route_trading_revenue[route] =
SUM(daily_trading_revenue_for_every_route_&_airline[route,*])
total_trading_revenue(t) = total_trading_revenue(t - dt) + (daily_trading_revenue) * dt
INIT total_trading_revenue = 0
daily_trading_revenue = SUM(daily_route_trading_revenue)
total_trading_revenue_for_every_route_&_airline[route, airlines](t) =
total_trading_revenue_for_every_route_&_airline[route, airlines](t - dt) +
(daily_trading_revenue_for_every_route_&_airline[route, airlines]) * dt
INIT total_trading_revenue_for_every_route_&_airline[route, airlines] = 0
daily_trading_revenue_for_every_route_&_airline[route, airlines] =
traffic_volume.daily_passengers_for_every_route_&_airline[route,airlines]*(average_sp
ending_per_pax+step(percentage_of_change_on_spending_on_shopping*demand.averag
ge_spending_change_per_pax, 60))
average_spending_per_pax = 11
UNITS: RMB/pax
A2 Detailed Stock and Flow Diagram of High-Level Model of Airport Revenue
A3 Route Map for Nanjing Airport

Figure A3.1 23 Domestic Routes without Competition for NKG in Chapter 5

Figure A3.2 Seven Domestic Routes with competition from HSR for NKG in Chapter 6
A4 Results in Chapter 4

Table A4.1 Simulation Results of Applying Dual-Till Pricing for Light-Handed (Case 1) and Price-Cap (Case 3) Regulations for Nanjing Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flight, Pax(100,000)</th>
<th>Charge rate, (¥/pax)</th>
<th>Aero revenue, (¥, million)</th>
<th>Non-aero revenue, (¥, million)</th>
<th>Total revenue, (¥, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>64,591</td>
<td>69.69</td>
<td>79</td>
<td>275.28</td>
<td>243.92</td>
</tr>
<tr>
<td>2007</td>
<td>67,471</td>
<td>74.22</td>
<td>63.12</td>
<td>234.25</td>
<td>259.76</td>
</tr>
<tr>
<td>2008</td>
<td>96,944</td>
<td>94.82</td>
<td>52.98</td>
<td>251.18</td>
<td>331.88</td>
</tr>
<tr>
<td>2009</td>
<td>99,824</td>
<td>109.81</td>
<td>46.26</td>
<td>253.99</td>
<td>384.32</td>
</tr>
<tr>
<td>2010</td>
<td>102,898</td>
<td>113.19</td>
<td>49.03</td>
<td>277.48</td>
<td>396.16</td>
</tr>
<tr>
<td>2011</td>
<td>152,118</td>
<td>144.32</td>
<td>51.99</td>
<td>375.18</td>
<td>505.13</td>
</tr>
<tr>
<td>2012</td>
<td>154,998</td>
<td>164.63</td>
<td>57.38</td>
<td>472.32</td>
<td>576.21</td>
</tr>
</tbody>
</table>

Table A4.2 Simulation Results of Applying Single-Till Pricing for Light-Handed (Case 2) and Price-Cap (Case 4) Regulations for Nanjing Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flight, Pax(100,000)</th>
<th>Charge rate, (¥/pax)</th>
<th>Aero revenue, (¥, million)</th>
<th>Non-aero revenue, (¥, million)</th>
<th>Total revenue, (¥, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>64,591</td>
<td>69.69</td>
<td>79</td>
<td>275.28</td>
<td>243.92</td>
</tr>
<tr>
<td>2007</td>
<td>67,471</td>
<td>74.22</td>
<td>51.34</td>
<td>190.51</td>
<td>259.76</td>
</tr>
<tr>
<td>2008</td>
<td>100,686</td>
<td>96.90</td>
<td>33.28</td>
<td>161.25</td>
<td>339.15</td>
</tr>
<tr>
<td>2009</td>
<td>103,566</td>
<td>113.11</td>
<td>20.32</td>
<td>114.90</td>
<td>395.89</td>
</tr>
<tr>
<td>2010</td>
<td>106,446</td>
<td>117.09</td>
<td>24.73</td>
<td>144.79</td>
<td>409.82</td>
</tr>
<tr>
<td>2011</td>
<td>154,019</td>
<td>147.89</td>
<td>29.77</td>
<td>220.15</td>
<td>517.60</td>
</tr>
<tr>
<td>2012</td>
<td>156,899</td>
<td>167.40</td>
<td>40.5</td>
<td>339.03</td>
<td>585.92</td>
</tr>
</tbody>
</table>

Table A4.3 Simulation Results for Case 1 – Impact of Light-Handed & Dual Till Regime on Perth Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flights</th>
<th>Paxs (100,000)</th>
<th>Charge rates (AUD/pax)</th>
<th>Aero revenues (AUD, million)</th>
<th>Non-aero revenues (AUD, million)</th>
<th>Total revenues (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.08</td>
<td>83.65</td>
<td>121.73</td>
</tr>
<tr>
<td>2003</td>
<td>54,530</td>
<td>59.13</td>
<td>7.57</td>
<td>44.74</td>
<td>92.75</td>
<td>137.49</td>
</tr>
<tr>
<td>2004</td>
<td>57,410</td>
<td>65.63</td>
<td>7.57</td>
<td>49.70</td>
<td>102.95</td>
<td>152.65</td>
</tr>
<tr>
<td>2005</td>
<td>60,290</td>
<td>72.80</td>
<td>7.84</td>
<td>57.09</td>
<td>114.19</td>
<td>171.28</td>
</tr>
<tr>
<td>2006</td>
<td>63,170</td>
<td>80.84</td>
<td>7.67</td>
<td>62.04</td>
<td>126.80</td>
<td>188.84</td>
</tr>
<tr>
<td>2007</td>
<td>66,050</td>
<td>85.87</td>
<td>7.76</td>
<td>66.64</td>
<td>134.69</td>
<td>201.33</td>
</tr>
<tr>
<td>2008</td>
<td>71,886</td>
<td>93.45</td>
<td>8.35</td>
<td>78.01</td>
<td>146.59</td>
<td>224.60</td>
</tr>
<tr>
<td>2009</td>
<td>79,358</td>
<td>103.17</td>
<td>8.61</td>
<td>88.83</td>
<td>161.83</td>
<td>250.66</td>
</tr>
<tr>
<td>2010</td>
<td>87,710</td>
<td>114.02</td>
<td>9.13</td>
<td>104.11</td>
<td>178.86</td>
<td>282.97</td>
</tr>
<tr>
<td>2011</td>
<td>96,908</td>
<td>125.98</td>
<td>9.53</td>
<td>120.11</td>
<td>222.32</td>
<td>342.43</td>
</tr>
<tr>
<td>2012</td>
<td>107,133</td>
<td>139.27</td>
<td>11.39</td>
<td>158.61</td>
<td>273.08</td>
<td>431.69</td>
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</table>
Table A4.4 Simulation Results for Case 2 – Impact of Light-Handed & Single-Till, Rate of Return 22.8% on Perth Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flights</th>
<th>Paxs (100,000)</th>
<th>Charge rates (AUD/pax)</th>
<th>Aero revenues (AUD, million)</th>
<th>Non-aero revenues (AUD, million)</th>
<th>Total revenues (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.08</td>
<td>83.65</td>
<td>121.73</td>
</tr>
<tr>
<td>2003</td>
<td>54,530</td>
<td>59.92</td>
<td>2.48</td>
<td>14.86</td>
<td>93.99</td>
<td>108.85</td>
</tr>
<tr>
<td>2004</td>
<td>57,410</td>
<td>66.70</td>
<td>1.35</td>
<td>9.00</td>
<td>104.64</td>
<td>113.63</td>
</tr>
<tr>
<td>2005</td>
<td>60,290</td>
<td>74.31</td>
<td>0</td>
<td>0.00</td>
<td>116.56</td>
<td>116.56</td>
</tr>
<tr>
<td>2006</td>
<td>63,170</td>
<td>82.12</td>
<td>1.4</td>
<td>11.52</td>
<td>128.82</td>
<td>140.33</td>
</tr>
<tr>
<td>2007</td>
<td>66,088</td>
<td>85.91</td>
<td>2.66</td>
<td>22.85</td>
<td>134.77</td>
<td>157.62</td>
</tr>
<tr>
<td>2008</td>
<td>72,806</td>
<td>94.65</td>
<td>4.21</td>
<td>39.81</td>
<td>148.47</td>
<td>188.27</td>
</tr>
<tr>
<td>2009</td>
<td>80,178</td>
<td>104.23</td>
<td>4.56</td>
<td>47.52</td>
<td>163.50</td>
<td>211.02</td>
</tr>
<tr>
<td>2010</td>
<td>88,598</td>
<td>115.18</td>
<td>3.98</td>
<td>45.79</td>
<td>180.67</td>
<td>226.46</td>
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<tr>
<td>2011</td>
<td>98,168</td>
<td>127.62</td>
<td>11.62</td>
<td>148.24</td>
<td>225.21</td>
<td>373.45</td>
</tr>
<tr>
<td>2012</td>
<td>106,508</td>
<td>138.46</td>
<td>14.43</td>
<td>199.84</td>
<td>271.49</td>
<td>471.33</td>
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</table>

Table A4.5 Simulation Results for Case 3 – Impact of Price-Cap & Dual-Till (Assumed Price-Cap=AUD 10) on Perth Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flights</th>
<th>Paxs (100,000)</th>
<th>Charge rates (AUD/pax)</th>
<th>Aero revenues (AUD, million)</th>
<th>Non-aero revenues (AUD, million)</th>
<th>Total revenues (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.08</td>
<td>83.65</td>
<td>121.73</td>
</tr>
<tr>
<td>2003</td>
<td>54,530</td>
<td>59.13</td>
<td>7.57</td>
<td>44.74</td>
<td>92.75</td>
<td>137.49</td>
</tr>
<tr>
<td>2004</td>
<td>57,410</td>
<td>65.63</td>
<td>7.57</td>
<td>49.70</td>
<td>102.95</td>
<td>152.65</td>
</tr>
<tr>
<td>2005</td>
<td>60,290</td>
<td>72.80</td>
<td>7.84</td>
<td>57.09</td>
<td>114.19</td>
<td>171.28</td>
</tr>
<tr>
<td>2006</td>
<td>63,170</td>
<td>80.84</td>
<td>7.67</td>
<td>62.04</td>
<td>126.80</td>
<td>188.84</td>
</tr>
<tr>
<td>2007</td>
<td>66,050</td>
<td>85.87</td>
<td>7.76</td>
<td>66.64</td>
<td>134.69</td>
<td>201.33</td>
</tr>
<tr>
<td>2008</td>
<td>71,886</td>
<td>93.45</td>
<td>8.35</td>
<td>78.01</td>
<td>146.59</td>
<td>224.60</td>
</tr>
<tr>
<td>2009</td>
<td>79,358</td>
<td>103.17</td>
<td>8.61</td>
<td>88.83</td>
<td>161.83</td>
<td>250.66</td>
</tr>
<tr>
<td>2010</td>
<td>87,710</td>
<td>114.02</td>
<td>9.13</td>
<td>104.11</td>
<td>178.86</td>
<td>282.97</td>
</tr>
<tr>
<td>2011</td>
<td>96,908</td>
<td>125.98</td>
<td>9.53</td>
<td>120.11</td>
<td>222.32</td>
<td>342.43</td>
</tr>
<tr>
<td>2012</td>
<td>107,133</td>
<td>139.27</td>
<td>10</td>
<td>139.27</td>
<td>273.08</td>
<td>412.36</td>
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</table>

Table A4.6 Simulation Results for Case 4 – Impact of Price-Cap & Single-Till (Assumed Price-Cap=AUD 10) on Perth Airport

<table>
<thead>
<tr>
<th>Year</th>
<th>Flights</th>
<th>Paxs (100,000)</th>
<th>Charge rates (AUD/pax)</th>
<th>Aero revenues (AUD, million)</th>
<th>Non-aero revenues (AUD, million)</th>
<th>Total revenues (AUD, million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>51,650</td>
<td>53.33</td>
<td>7.14</td>
<td>38.08</td>
<td>83.65</td>
<td>121.73</td>
</tr>
<tr>
<td>2003</td>
<td>54,530</td>
<td>59.92</td>
<td>2.48</td>
<td>14.86</td>
<td>93.99</td>
<td>108.85</td>
</tr>
<tr>
<td>2004</td>
<td>57,410</td>
<td>66.70</td>
<td>1.35</td>
<td>9.00</td>
<td>104.64</td>
<td>113.63</td>
</tr>
<tr>
<td>2005</td>
<td>60,290</td>
<td>74.31</td>
<td>0</td>
<td>0.00</td>
<td>116.56</td>
<td>116.56</td>
</tr>
<tr>
<td>2006</td>
<td>63,170</td>
<td>82.12</td>
<td>1.4</td>
<td>11.52</td>
<td>128.82</td>
<td>140.33</td>
</tr>
<tr>
<td>2007</td>
<td>66,088</td>
<td>85.91</td>
<td>2.66</td>
<td>22.85</td>
<td>134.77</td>
<td>157.62</td>
</tr>
<tr>
<td>2008</td>
<td>72,806</td>
<td>94.65</td>
<td>4.21</td>
<td>39.81</td>
<td>148.47</td>
<td>188.27</td>
</tr>
<tr>
<td>2009</td>
<td>80,178</td>
<td>104.23</td>
<td>4.56</td>
<td>47.52</td>
<td>163.50</td>
<td>211.02</td>
</tr>
<tr>
<td>2010</td>
<td>88,598</td>
<td>115.18</td>
<td>3.98</td>
<td>45.79</td>
<td>180.67</td>
<td>226.46</td>
</tr>
<tr>
<td>2011</td>
<td>98,168</td>
<td>127.62</td>
<td>10</td>
<td>127.62</td>
<td>225.21</td>
<td>352.83</td>
</tr>
<tr>
<td>2012</td>
<td>106,959</td>
<td>139.05</td>
<td>10</td>
<td>139.05</td>
<td>272.64</td>
<td>411.69</td>
</tr>
</tbody>
</table>
### A5 Results in Chapter 5

Table A5.1 Discounted Airfare for All Routes (¥) at NKG

<table>
<thead>
<tr>
<th></th>
<th>Changchun</th>
<th>Chengdu</th>
<th>Dalian</th>
<th>Fuzhou</th>
<th>Guangzhou</th>
<th>Guiyang</th>
<th>Guiling</th>
<th>Harbin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High 0.7*price cap (¥)</strong></td>
<td>1,022</td>
<td>1,078</td>
<td>651</td>
<td>525</td>
<td>826</td>
<td>910</td>
<td>777</td>
<td>1,155</td>
</tr>
<tr>
<td><strong>Cheap 0.3*price cap (¥)</strong></td>
<td>438</td>
<td>462</td>
<td>279</td>
<td>225</td>
<td>354</td>
<td>390</td>
<td>333</td>
<td>495</td>
</tr>
</tbody>
</table>

Table A5.1 Discounted Airfare for All Routes (continued)

<table>
<thead>
<tr>
<th></th>
<th>Haikou</th>
<th>Kunming</th>
<th>Nanchang</th>
<th>Nanning</th>
<th>Sanya</th>
<th>Shenzhen</th>
<th>Shenyang</th>
<th>Shijiazhuang</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High 0.7*price cap (¥)</strong></td>
<td>1,295</td>
<td>1,225</td>
<td>462</td>
<td>1,036</td>
<td>1,281</td>
<td>966</td>
<td>1,022</td>
<td>595</td>
</tr>
<tr>
<td><strong>Cheap 0.3*price cap (¥)</strong></td>
<td>555</td>
<td>525</td>
<td>198</td>
<td>444</td>
<td>549</td>
<td>414</td>
<td>438</td>
<td>255</td>
</tr>
</tbody>
</table>

Table A5.1 Discounted Airfare for All Routes (continued)

<table>
<thead>
<tr>
<th></th>
<th>Taiyuan</th>
<th>Xian</th>
<th>Xiamen</th>
<th>Yinchuan</th>
<th>Zhangjiajie</th>
<th>Zhengzhou</th>
<th>Chongqing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High 0.7*price cap (¥)</strong></td>
<td>616</td>
<td>756</td>
<td>686</td>
<td>1,155</td>
<td>658</td>
<td>483</td>
<td>896</td>
</tr>
<tr>
<td><strong>Cheap 0.3*price cap (¥)</strong></td>
<td>264</td>
<td>324</td>
<td>294</td>
<td>495</td>
<td>282</td>
<td>207</td>
<td>384</td>
</tr>
</tbody>
</table>

Table A5.2 Impact of Decreasing the Aeronautical Charge Rate on Airport and Airline Revenues for Nanjing (High Airfares = 70% of price-cap, APP =1)

<table>
<thead>
<tr>
<th></th>
<th>Case 1/baseline (standard charge rate * applied)</th>
<th>Case 2 (charge rate decreased by 20%)</th>
<th>Case 3 (charge rate decreased by 40%)</th>
<th>Case 4 (charge rate decreased by 60%)</th>
<th>Case 5 (charge rate decreased by 80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total pax volume</strong></td>
<td>10,605.356</td>
<td>10,625.980</td>
<td>10,891.713</td>
<td>11,030.445</td>
<td>11,187.919</td>
</tr>
<tr>
<td><strong>Total flight volume</strong></td>
<td>85,082</td>
<td>85,082</td>
<td>85,158</td>
<td>85,794</td>
<td>88,000</td>
</tr>
<tr>
<td><strong>Total airport revenues</strong></td>
<td>523.979</td>
<td>511.328</td>
<td>410.125</td>
<td>351.155</td>
<td>291.306</td>
</tr>
<tr>
<td><strong>Aero revenues</strong></td>
<td>333.613</td>
<td>320.592</td>
<td>214.619</td>
<td>153.159</td>
<td>90.483</td>
</tr>
<tr>
<td><strong>Non-aero revenues</strong></td>
<td>190.366</td>
<td>190.736</td>
<td>195.506</td>
<td>197.996</td>
<td>200.823</td>
</tr>
<tr>
<td><strong>Airline revenues</strong></td>
<td>8,766.118</td>
<td>8,781.324</td>
<td>8,900.780</td>
<td>8,964.251</td>
<td>9,035.405</td>
</tr>
</tbody>
</table>

*In this thesis, total airline revenue = airline revenues from tickets sale – airport charges paid to the airport.
Table A5.3 Impact of Decreasing the Aeronautical Charge Rate on Airport and Airline Revenues for Nanjing (Cheap Airfares = 30% of price-cap, APP = 1)

<table>
<thead>
<tr>
<th>Case</th>
<th>Case 2 (charge rate decreased by 20%)</th>
<th>Case 3 (charge rate decreased by 40%)</th>
<th>Case 4 (charge rate decreased by 60%)</th>
<th>Case 5 (charge rate decreased by 80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume (1000’s passengers)</td>
<td>10,605.356</td>
<td>10,653.221</td>
<td>11,289.107</td>
<td>11,650.403</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>85.082</td>
<td>85.082</td>
<td>89.386</td>
<td>93.020</td>
</tr>
<tr>
<td>Total airport revenues (million ¥)</td>
<td>523.979</td>
<td>512.484</td>
<td>425.269</td>
<td>370.845</td>
</tr>
<tr>
<td>Aero revenues (million ¥)</td>
<td>333.613</td>
<td>321.259</td>
<td>222.630</td>
<td>161.720</td>
</tr>
<tr>
<td>Airline revenues (million ¥)</td>
<td>3,595.784</td>
<td>3,652.260</td>
<td>3,707.954</td>
<td>3,766.621</td>
</tr>
</tbody>
</table>

Note: *standard charge rate: Landing charge rate - about ¥ 1,734/ per departing flight; Terminal charge rate - ¥ 42/ per departing passenger; Security charger rate: ¥ 7/ per departing passenger.

Table A5.4 Impact of Increasing the Aeronautical Charge Rate on Airport and Airline Revenues for Nanjing (High Airfares = 70% of price-cap, APP = 1)

<table>
<thead>
<tr>
<th>Case</th>
<th>Case 2 (charge rate increased by 20%)</th>
<th>Case 3 (charge rate increased by 40%)</th>
<th>Case 4 (charge rate increased by 60%)</th>
<th>Case 5 (charge rate increased by 80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume (1000’s passengers)</td>
<td>10,605.356</td>
<td>10,450.643</td>
<td>10,293.354</td>
<td>10,056.415</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>85.082</td>
<td>85.082</td>
<td>85.082</td>
<td>84.068</td>
</tr>
<tr>
<td>Total airport revenues (million ¥)</td>
<td>523.979</td>
<td>578.275</td>
<td>630.920</td>
<td>676.563</td>
</tr>
<tr>
<td>Aero revenues (million ¥)</td>
<td>333.613</td>
<td>390.686</td>
<td>446.154</td>
<td>496.050</td>
</tr>
<tr>
<td>Non-aero revenues (million ¥)</td>
<td>190.366</td>
<td>187.589</td>
<td>184.766</td>
<td>180.513</td>
</tr>
<tr>
<td>Airline revenues (million ¥)</td>
<td>8,766.118</td>
<td>8,687.409</td>
<td>8,604.076</td>
<td>8,452.423</td>
</tr>
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</table>

Table A5.5 Impact of Increasing the Aeronautical Charge Rate on Airport and Airline Revenues for Nanjing (Cheap Airfares = 30% of price-cap, APP = 1)

<table>
<thead>
<tr>
<th>Case</th>
<th>Case 2 (charge rate increased by 20%)</th>
<th>Case 3 (charge rate increased by 40%)</th>
<th>Case 4 (charge rate increased by 60%)</th>
<th>Case 5 (charge rate increased by 80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume (1000’s passengers)</td>
<td>10,605.356</td>
<td>10,230.203</td>
<td>9,760.088</td>
<td>9,125.855</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>85.082</td>
<td>84.920</td>
<td>83.322</td>
<td>79.972</td>
</tr>
<tr>
<td>Total airport revenues (million ¥)</td>
<td>523.979</td>
<td>567.738</td>
<td>601.440</td>
<td>618.174</td>
</tr>
<tr>
<td>Aero revenues (million ¥)</td>
<td>333.613</td>
<td>384.106</td>
<td>426.247</td>
<td>454.365</td>
</tr>
</tbody>
</table>
Case 1 (baseline (standard charge rate applied)) | Case 2 (charge rate increased by 20%) | Case 3 (charge rate increased by 40%) | Case 4 (charge rate increased by 60%) | Case 5 (charge rate increased by 80%)
---|---|---|---|---
Non-aero revenues (million ¥) | 190.366 | 183.632 | 175.194 | 163.809 | 149.172
Airline revenues (million ¥) | 3,566.272 | 3,485.381 | 3,370.683 | 3,208.094 | 2,983.960

Table A5.6 Impact of Changing Aeronautical Charge Rate on Two Routes with Lower SLF for Nanjing (Airfare Level = 0.7)

| | Case 1 (baseline (standard charge rate applied)) | Case 2 (charge rate increased by 20%) | Case 3 (charge rate increased by 40%) | Case 4 (charge rate increased by 60%) | Case 5 (charge rate increased by 80%)
---|---|---|---|---|---
Nanning (¥ 1,480) | | | | | |
Total pax volume (people) | 226,713 | 224,069 | 221,425 | 182,256 | 175,543
Total flight volume (flights) | 2,160 | 2,160 | 2,160 | 1,650 | 1,584
Total airport revenue per route (¥) | 11,207,679 | 12,401,062 | 13,568,533 | 12,292,942 | 12,867,480
Xiamen (¥ 980) | | | | | |
Total pax volume (people) | 408,029 | 400,778 | 393,527 | 346,993 | 329,646
Total flight volume (flights) | 3,600 | 3,600 | 3,600 | 3,144 | 2,978
Total airport revenue per route (¥) | 20,356,342 | 22,420,092 | 24,412,781 | 23,576,788 | 24,327,098

Table A5.7 Impact of Changing Aeronautical Charge Rate on Eight Routes with Lower SLF for Nanjing (Airfare Level = 0.3)

| | Case 1 (baseline (standard charge rate applied)) | Case 2 (charge rate increased by 20%) | Case 3 (charge rate increased by 40%) | Case 4 (charge rate increased by 60%) | Case 5 (charge rate increased by 80%)
---|---|---|---|---|---
Nanchang (¥ 660) | | | | | |
Total pax volume (people) | 226,713 | 210,134 | 171,252 | 165,633 | 160,393
Total flight volume (flights) | 2,160 | 1,998 | 1,548 | 1,508 | 1,478
Total airport revenue per route (¥) | 11,207,679 | 11,642,849 | 10,569,893 | 11,204,561 | 11,800,633
Xiamen (¥ 980) | | | | | |
Total pax volume (people) | 408,029 | 391,110 | 323,403 | 304,579 | 285,226
Total flight volume (flights) | 3,600 | 3,600 | 2,948 | 2,828 | 2,656
Total airport revenue per route (¥) | 20,356,342 | 21,962,315 | 20,101,230 | 20,766,490 | 21,083,778
<table>
<thead>
<tr>
<th></th>
<th>Case 1/baseline (standard charge rate applied)</th>
<th>Case 2 (charge rate increased by 20%)</th>
<th>Case 3 (charge rate increased by 40%)</th>
<th>Case 4 (charge rate increased by 60%)</th>
<th>Case 5 (charge rate increased by 80%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuzhou (¥ 750)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>410,933</td>
<td>388,922</td>
<td>366,912</td>
<td>316,662</td>
<td>289,388</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>3,600</td>
<td>3,600</td>
<td>3,600</td>
<td>2,960</td>
<td>2,754</td>
</tr>
<tr>
<td>Total airport revenue per route (¥)</td>
<td>20,261,911</td>
<td>21,600,004</td>
<td>22,722,494</td>
<td>21,513,377</td>
<td>21,381,274</td>
</tr>
<tr>
<td><strong>Guiling (¥ 1,110)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>278,255</td>
<td>268,155</td>
<td>258,056</td>
<td>108,547</td>
<td>80,573</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>2,160</td>
<td>2,160</td>
<td>2,160</td>
<td>964</td>
<td>718</td>
</tr>
<tr>
<td>Total airport revenue (¥)</td>
<td>13,760,656</td>
<td>14,901,698</td>
<td>15,943,839</td>
<td>7,193,367</td>
<td>5,630,006</td>
</tr>
<tr>
<td><strong>Taiyuan (¥ 880)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>669,062</td>
<td>638,821</td>
<td>608,583</td>
<td>496,002</td>
<td>353,315</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>5,040</td>
<td>5,040</td>
<td>5,040</td>
<td>4,160</td>
<td>2,890</td>
</tr>
<tr>
<td>Total airport revenue per route (¥)</td>
<td>32,654,006</td>
<td>35,036,139</td>
<td>37,122,092</td>
<td>33,010,845</td>
<td>25,221,682</td>
</tr>
<tr>
<td><strong>Dalian (¥930)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>562,450</td>
<td>538,294</td>
<td>514,109</td>
<td>489,927</td>
<td>355,022</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>4,320</td>
<td>4,320</td>
<td>4,320</td>
<td>4,320</td>
<td>3,238</td>
</tr>
<tr>
<td>Total airport revenue per route (¥)</td>
<td>27,603,717</td>
<td>29,694,284</td>
<td>31,546,625</td>
<td>33,162,103</td>
<td>25,971,688</td>
</tr>
<tr>
<td><strong>Shenyang (¥ 1,460)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>361,288</td>
<td>351,184</td>
<td>341,082</td>
<td>326,661</td>
<td>271,709</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>3,120</td>
<td>3,120</td>
<td>3,120</td>
<td>3,082</td>
<td>2,654</td>
</tr>
<tr>
<td>Total airport revenue per route (¥)</td>
<td>18,110,150</td>
<td>19,778,792</td>
<td>21,348,521</td>
<td>22,516,191</td>
<td>20,382,481</td>
</tr>
<tr>
<td><strong>Xian (¥ 1,080)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (people)</td>
<td>800,991</td>
<td>771,343</td>
<td>741,654</td>
<td>711,969</td>
<td>560,297</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>6,480</td>
<td>6,480</td>
<td>6,480</td>
<td>6,480</td>
<td>4,782</td>
</tr>
<tr>
<td>Total airport revenue (¥)</td>
<td>39,354,130</td>
<td>42,564,300</td>
<td>45,481,786</td>
<td>48,108,537</td>
<td>40,521,569</td>
</tr>
</tbody>
</table>
Table A5.8 Impact of Decreasing Aeronautical Charge Rate on Airport and Airlines Revenue with High airfare for Nanjing (Airfare Level = 0.7 of Price-Cap; APP = 0)

<table>
<thead>
<tr>
<th>Case</th>
<th>Total airport revenue (million ¥)</th>
<th>Airline revenue (million ¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/baseline</td>
<td>523.979</td>
<td>8,766.118</td>
</tr>
<tr>
<td>2</td>
<td>510.452</td>
<td>8,779.644</td>
</tr>
<tr>
<td>3</td>
<td>400.736</td>
<td>8,889.361</td>
</tr>
<tr>
<td>4</td>
<td>339.115</td>
<td>8,950.982</td>
</tr>
<tr>
<td>5</td>
<td>277.493</td>
<td>9,012.604</td>
</tr>
</tbody>
</table>

Table A5.9 Impact of Decreasing Aeronautical Charge Rate on Airport and Airlines Revenue with Low Airfare for Nanjing (Airfare Level = 0.3 of Price-cap; APP = 0)

<table>
<thead>
<tr>
<th>Case</th>
<th>Total airport revenue (million ¥)</th>
<th>Airline revenue (million ¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/baseline</td>
<td>523.979</td>
<td>3,566.271</td>
</tr>
<tr>
<td>2</td>
<td>510.452</td>
<td>3,579.798</td>
</tr>
<tr>
<td>3</td>
<td>400.736</td>
<td>3,689.515</td>
</tr>
<tr>
<td>4</td>
<td>339.115</td>
<td>3,751.136</td>
</tr>
<tr>
<td>5</td>
<td>277.493</td>
<td>3,812.758</td>
</tr>
</tbody>
</table>

Table A5.10 Impact of Increasing Aeronautical Charge Rate on Airport and Airlines Revenue with High Airfare for Nanjing (Airfare Level = 0.7 of Price-Cap; APP = 0)

<table>
<thead>
<tr>
<th>Case</th>
<th>Total airport revenue (million ¥)</th>
<th>Airline revenue (million ¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/baseline</td>
<td>523.979</td>
<td>8,766.118</td>
</tr>
<tr>
<td>2</td>
<td>585.600</td>
<td>8,704.497</td>
</tr>
<tr>
<td>3</td>
<td>647.222</td>
<td>8,642.875</td>
</tr>
<tr>
<td>4</td>
<td>708.843</td>
<td>8,581.254</td>
</tr>
<tr>
<td>5</td>
<td>770.465</td>
<td>8,519.632</td>
</tr>
</tbody>
</table>

Table A5.11 Impact of Increasing Aeronautical Charge Rate on Airport and Airlines Revenue with Low Airfare for Nanjing (Airfare Level = 0.3 of Price-cap; APP = 0)

<table>
<thead>
<tr>
<th>Case</th>
<th>Total airport revenue (million ¥)</th>
<th>Airline revenue (million ¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/baseline</td>
<td>523.979</td>
<td>3,566.272</td>
</tr>
<tr>
<td>2</td>
<td>585.600</td>
<td>3,504.650</td>
</tr>
<tr>
<td>3</td>
<td>647.222</td>
<td>3,443.029</td>
</tr>
<tr>
<td>4</td>
<td>708.843</td>
<td>3,381.408</td>
</tr>
<tr>
<td>5</td>
<td>770.465</td>
<td>3,319.786</td>
</tr>
</tbody>
</table>
Table A5.12 Impact of the Airport Charge on the General Airport Revenue in Perth (Five Domestic Routes)

<table>
<thead>
<tr>
<th></th>
<th>Base charge rate decreased by 80%</th>
<th>Base charge rate decreased by 60%</th>
<th>Base charge rate decreased by 40%</th>
<th>Base charge rate decreased by 20%</th>
<th>Baseline-published charge rate*</th>
<th>Base charge rate increased by 20%</th>
<th>Base charge rate increased by 40%</th>
<th>Base charge rate increased by 60%</th>
<th>Base charge rate increased by 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume</td>
<td>5,978.951</td>
<td>5,939.806</td>
<td>5,900.042</td>
<td>5,860.053</td>
<td>5,800.614</td>
<td>5,760.845</td>
<td>5,721.075</td>
<td>5,681.305</td>
<td>5,628.712</td>
</tr>
<tr>
<td>Total flight volume</td>
<td>30,600</td>
<td>30,600</td>
<td>30,600</td>
<td>30,600</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,202</td>
</tr>
<tr>
<td>Total airport</td>
<td>69.663</td>
<td>81.716</td>
<td>93.300</td>
<td>104.886</td>
<td>115.246</td>
<td>126.377</td>
<td>136.723</td>
<td>146.786</td>
<td>156.336</td>
</tr>
<tr>
<td>revenue (million AUD)</td>
<td>18.433</td>
<td>30.806</td>
<td>42.890</td>
<td>54.684</td>
<td>65.786</td>
<td>76.930</td>
<td>87.787</td>
<td>98.358</td>
<td>108.163</td>
</tr>
<tr>
<td>Aero revenue</td>
<td>51.230</td>
<td>50.910</td>
<td>50.410</td>
<td>50.201</td>
<td>49.459</td>
<td>49.448</td>
<td>48.936</td>
<td>48.428</td>
<td>48.174</td>
</tr>
<tr>
<td>Non-aero revenue</td>
<td>1,415.658</td>
<td>1,407.071</td>
<td>1,398.375</td>
<td>1,389.611</td>
<td>1,374.674</td>
<td>1,365.925</td>
<td>1,357.152</td>
<td>1,348.355</td>
<td>1,335.461</td>
</tr>
</tbody>
</table>
| * Landing rate is AUD 4 per arriving and departing domestic passenger, the terminal rate is AUD 15 per arriving and the departing passenger, the security rate is AUD 3.6 per departing passenger.

Table A5.13 Impact of Changing Aeronautical Charge Rate on the Darwin route

<table>
<thead>
<tr>
<th></th>
<th>Base charge rate decreased by 80%</th>
<th>Base charge rate decreased by 60%</th>
<th>Base charge rate decreased by 40%</th>
<th>Base charge rate decreased by 20%</th>
<th>Baseline-published charge rate*</th>
<th>Base charge rate increased by 20%</th>
<th>Base charge rate increased by 40%</th>
<th>Base charge rate increased by 60%</th>
<th>Base charge rate increased by 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pax volume</td>
<td>131,732</td>
<td>131,145</td>
<td>130,559</td>
<td>129,973</td>
<td>109,936</td>
<td>109,569</td>
<td>109,202</td>
<td>108,835</td>
<td>95,644</td>
</tr>
<tr>
<td>Total flight volume</td>
<td>1,320</td>
<td>1,320</td>
<td>1,320</td>
<td>1,320</td>
<td>1,072</td>
<td>1,072</td>
<td>1,072</td>
<td>1,072</td>
<td>922</td>
</tr>
<tr>
<td>Total airport</td>
<td>1,500,418</td>
<td>1,747,582</td>
<td>1,985,608</td>
<td>2,225,918</td>
<td>1,884,885</td>
<td>2,045,694</td>
<td>2,198,517</td>
<td>2,347,373</td>
<td>1,910,474</td>
</tr>
<tr>
<td>revenue (AUD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table A5.14 Impact of Decreasing the Aeronautical Charge Rate on Airport and Airlines Revenue for Perth (High Airfare Level; APP =0 vs APP=1)

<table>
<thead>
<tr>
<th>APP=0</th>
<th>Base charge rate decreased by 80%</th>
<th>Base charge rate decreased by 60%</th>
<th>Base charge rate decreased by 40%</th>
<th>Base charge rate decreased by 20%</th>
<th>Baseline-published charge rate*</th>
<th>Base charge rate increased by 20%</th>
<th>Base charge rate increased by 40%</th>
<th>Base charge rate increased by 60%</th>
<th>Base charge rate increased by 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total pax volume (1000’s passengers)</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
<td>5,800.614</td>
</tr>
<tr>
<td></td>
<td>Total flight volume (flights)</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue (million AUD)</td>
<td>67.057</td>
<td>79.246</td>
<td>91.376</td>
<td>103.790</td>
<td>115.436</td>
<td>127.325</td>
<td>139.438</td>
<td>151.637</td>
</tr>
<tr>
<td></td>
<td>Airline revenue (million AUD)</td>
<td>5,179.262</td>
<td>5,167.261</td>
<td>5,155.260</td>
<td>5,143.258</td>
<td>5,131.257</td>
<td>5,119.256</td>
<td>5,107.254</td>
<td>5,095.253</td>
</tr>
<tr>
<td>APP=1</td>
<td>Total pax volume (1000’s passengers)</td>
<td>5,907.962</td>
<td>5,886.201</td>
<td>5,864.156</td>
<td>5,822.616</td>
<td>5,800.614</td>
<td>5,778.612</td>
<td>5,756.610</td>
<td>5,734.609</td>
</tr>
<tr>
<td></td>
<td>Total flight volume (flights)</td>
<td>30,600</td>
<td>30,600</td>
<td>30,600</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue (million AUD)</td>
<td>68.605</td>
<td>80.653</td>
<td>92.681</td>
<td>103.947</td>
<td>115.411</td>
<td>126.575</td>
<td>137.772</td>
<td>148.873</td>
</tr>
<tr>
<td></td>
<td>Airline revenue (million AUD)</td>
<td>5,199.948</td>
<td>5,190.909</td>
<td>5,181.828</td>
<td>5,140.299</td>
<td>5,131.257</td>
<td>5,122.201</td>
<td>5,113.132</td>
<td>5,104.049</td>
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</table>
Table A5.15 Impact of Decreasing the Aeronautical Charge Rate on Airport and Airlines Revenue for Perth (Low Airfare Level; APP =0 vs APP=1)

<table>
<thead>
<tr>
<th>APP=0</th>
<th>Base charge rate decreased by 80%</th>
<th>Base charge rate decreased by 60%</th>
<th>Base charge rate decreased by 40%</th>
<th>Base charge rate decreased by 20%</th>
<th>Baseline-published charge rate*</th>
<th>Base charge rate increased by 20%</th>
<th>Base charge rate increased by 40%</th>
<th>Base charge rate increased by 60%</th>
<th>Base charge rate increased by 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport revenue (million AUD)</td>
<td>67.474</td>
<td>79.213</td>
<td>91.276</td>
<td>103.122</td>
<td>115.315</td>
<td>127.327</td>
<td>139.565</td>
<td>151.361</td>
<td>163.357</td>
</tr>
<tr>
<td>Airline revenue (AUD)</td>
<td>1,422.679</td>
<td>1,410.678</td>
<td>1,398.676</td>
<td>1,386.675</td>
<td>1,374.674</td>
<td>1,362.672</td>
<td>1,350.671</td>
<td>1,338.670</td>
<td>1,326.668</td>
</tr>
<tr>
<td>APP=1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total pax volume (1000’s passengers)</td>
<td>5,978.951</td>
<td>5,939.806</td>
<td>5,900.042</td>
<td>5,860.053</td>
<td>5,800.614</td>
<td>5,760.845</td>
<td>5,721.075</td>
<td>5,681.305</td>
<td>5,628.712</td>
</tr>
<tr>
<td>Total flight volume (flights)</td>
<td>30,600</td>
<td>30,600</td>
<td>30,600</td>
<td>30,600</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,352</td>
<td>30,202</td>
</tr>
<tr>
<td>Total airport revenue (million AUD)</td>
<td>69.663</td>
<td>81.716</td>
<td>93.300</td>
<td>104.886</td>
<td>115.315</td>
<td>126.377</td>
<td>136.723</td>
<td>146.786</td>
<td>156.336</td>
</tr>
<tr>
<td>Airline revenue (million AUD)</td>
<td>1,415.658</td>
<td>1,407.071</td>
<td>1,398.375</td>
<td>1,389.611</td>
<td>1,374.674</td>
<td>1,365.925</td>
<td>1,357.152</td>
<td>1,348.355</td>
<td>1,335.461</td>
</tr>
</tbody>
</table>

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A6 Results in Chapter 6

Table A6.1 Impact of the Airline Response Time

<table>
<thead>
<tr>
<th>Without HSR</th>
<th>With HSR (after HSR entering, the frequency and aircraft of all the airlines unchanged)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1/ Baseline</strong> (airfare = 0.7* price cap)</td>
<td><strong>Case 2</strong> (airfare = 0.7*price cap, unchanged)</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>3,305.65</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>163.65</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>2,037.79</td>
</tr>
<tr>
<td>Total annual flight (flight)</td>
<td>26,280</td>
</tr>
<tr>
<td>Airline revenue per flight (¥)</td>
<td>77,542</td>
</tr>
</tbody>
</table>

Table A6.2 Impact of Airfare Change before HSR Enters the Market

<table>
<thead>
<tr>
<th>Without HSR</th>
<th>With HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1/ Baseline</strong> (airfare = 0.7* price cap)</td>
<td><strong>Case 2</strong> (airfare = 0.7*price cap, unchanged)</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>3,305.65</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>163.65</td>
</tr>
<tr>
<td>Total airline revenue* (million ¥)</td>
<td>2,037.79</td>
</tr>
</tbody>
</table>

*In this thesis, total airline revenue = airline revenues from tickets sale – airport charges paid to the airport.

Table A6.3 Impact of Airfare Change after HSR Enters the Market

<table>
<thead>
<tr>
<th>Without HSR</th>
<th>With HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Case 1/ Baseline</strong> (airfare = 0.7* price cap)</td>
<td><strong>Case 2</strong> (airfare = 0.7*price cap, unchanged)</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>3,305.65</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>163.65</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>2,037.79</td>
</tr>
</tbody>
</table>
Table 6.4 Impacts of Change in Frequency of Flights When Airlines Respond before HSR Started Operation

<table>
<thead>
<tr>
<th>Case</th>
<th>Without HSR</th>
<th>With HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total airport pax (1000’s pax)</td>
<td>3,305.65</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue (million ¥)</td>
<td>163.65</td>
</tr>
<tr>
<td></td>
<td>Total airline revenue (million ¥)</td>
<td>2,037.79</td>
</tr>
<tr>
<td></td>
<td>Frequency (flights per day)</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Airline revenue per flight (¥)</td>
<td>77,542</td>
</tr>
</tbody>
</table>

Table 6.5 Impacts of Change in Frequency of Flights When Airlines Respond after HSR Enters the Market

<table>
<thead>
<tr>
<th>Case</th>
<th>Without HSR</th>
<th>With HSR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total airport pax (1000’s pax)</td>
<td>3,305.65</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue (million ¥)</td>
<td>163.65</td>
</tr>
<tr>
<td></td>
<td>Total airline revenue (million ¥)</td>
<td>2,037.79</td>
</tr>
<tr>
<td></td>
<td>Frequency (flights per day)</td>
<td>72</td>
</tr>
<tr>
<td></td>
<td>Airline revenue per flight (¥)</td>
<td>77,542</td>
</tr>
</tbody>
</table>
Table A6.6 Impact of Changes in the Airport Charge before HSR Enters the Market

<table>
<thead>
<tr>
<th>Case</th>
<th>Without HSR, 0.7 price, change frequency</th>
<th>Case 2</th>
<th>HSR, 0.7 price, change frequency</th>
<th>Case 3</th>
<th>HSR, 0.7 price, change frequency, airport charge -40%, before HSR entering, airlines pass it onto passengers</th>
<th>Case 4</th>
<th>HSR, 0.7 price, change frequency, airport charge -40%, before HSR entering, airlines keep the saving</th>
<th>Case 5</th>
<th>HSR, 0.5 price, change frequency, before HSR enters the market</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax (1000's pax)</td>
<td>3,305.65</td>
<td>1,286.41</td>
<td>1,454.10</td>
<td>1,286.41</td>
<td>2,350.63</td>
<td>163.65</td>
<td>64.82</td>
<td>55.42</td>
<td>49.19</td>
</tr>
<tr>
<td>Total airport revenue (million ¥ )</td>
<td>163.65</td>
<td>64.82</td>
<td>55.42</td>
<td>49.19</td>
<td>118.06</td>
<td>1,019.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airline revenue (million ¥ )</td>
<td>2,037.79</td>
<td>791.95</td>
<td>894.04</td>
<td>807.58</td>
<td>1,019.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency (flights per day)</td>
<td>74</td>
<td>29</td>
<td>30</td>
<td>29</td>
<td>57</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airline revenue per flight (¥)</td>
<td>77,542</td>
<td>68,454</td>
<td>69,134</td>
<td>69,805</td>
<td>49,474</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table A6.6 Continued

<table>
<thead>
<tr>
<th>Case 6</th>
<th>HSR, 0.5 price, change frequency, before HSR enter the market, airport charge -40%, airlines keep the saving</th>
<th>Case 7</th>
<th>HSR, 0.5 price, change frequency and aircraft, before HSR enters the market, airport charge -40%, airlines pass it onto passengers</th>
<th>Case 8</th>
<th>HSR, 0.3 price, change frequency, before HSR enters the market</th>
<th>Case 9</th>
<th>HSR, 0.3 price, change frequency, before HSR enter the market, airport charge -40%, airlines keep the saving</th>
<th>Case 10</th>
<th>HSR, 0.3 price, change frequency and aircraft, before HSR enters the market, airport charge -40%, airlines pass it onto passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>2,470.63</td>
<td>2,350.63</td>
<td>6,356.47</td>
<td>7,231.05</td>
<td>6,356.47</td>
<td>92.96</td>
<td>88.78</td>
<td>311.88</td>
<td>265.90</td>
</tr>
<tr>
<td>Total airport revenue (million ¥ )</td>
<td>1,051.76</td>
<td>1,048.45</td>
<td>1,587.02</td>
<td>1,727.07</td>
<td>1,665.07</td>
<td>1,019.17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airline revenue (million ¥ )</td>
<td>1,587.02</td>
<td>1,727.07</td>
<td>1,665.07</td>
<td>1,019.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency (flights per day)</td>
<td>55</td>
<td>57</td>
<td>149</td>
<td>173</td>
<td>149</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airline revenue per flight (¥)</td>
<td>49,868</td>
<td>50,896</td>
<td>33,490</td>
<td>31,975</td>
<td>35,137</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table A6.7 Impact of Changes in the Airport Charge after HSR Enters the Market

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Total airport pax (1000’s pax)</th>
<th>Total airport revenue (million ¥ )</th>
<th>Total airline revenue (million ¥ )</th>
<th>Frequency (flights per day)</th>
<th>Airline revenue per flight (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Without HSR, 0.7 price, change frequency</td>
<td>3,305.65</td>
<td>163.65</td>
<td>2,037.79</td>
<td>74</td>
<td>77,542</td>
</tr>
<tr>
<td>2</td>
<td>HSR, 0.7 price, change frequency</td>
<td>1,286.41</td>
<td>64.82</td>
<td>791.95</td>
<td>29</td>
<td>68,454</td>
</tr>
<tr>
<td>3</td>
<td>HSR, 0.7 price, change frequency, airport charge -40%, before HSR entering, airlines pass it onto passengers</td>
<td>1,313.30</td>
<td>52.18</td>
<td>800.30</td>
<td>29</td>
<td>68,274</td>
</tr>
<tr>
<td>4</td>
<td>HSR, 0.7 price, change frequency, airport charge -40%, before HSR entering, airlines keep the saving</td>
<td>1,286.41</td>
<td>51.22</td>
<td>805.55</td>
<td>29</td>
<td>69,630</td>
</tr>
<tr>
<td>5</td>
<td>HSR 0.5 price, change frequency, before HSR enters the market</td>
<td>1,699.92</td>
<td>84.87</td>
<td>780.26</td>
<td>34</td>
<td>54,419</td>
</tr>
</tbody>
</table>

Table A6.7 Continued

<table>
<thead>
<tr>
<th>Case</th>
<th>Description</th>
<th>Total airport pax (1000’s pax)</th>
<th>Total airport revenue (million ¥ )</th>
<th>Total airline revenue (million ¥ )</th>
<th>Frequency (flights per day)</th>
<th>Airline revenue per flight (¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>HSR 0.5 price, change frequency, before HSR enter the market, airport charge -40%, airlines keep the saving</td>
<td>1,856.16</td>
<td>72.09</td>
<td>837.32</td>
<td>37</td>
<td>53,102</td>
</tr>
<tr>
<td>7</td>
<td>HSR 0.5 price, change frequency and aircraft, before HSR enter the market</td>
<td>1,699.92</td>
<td>66.22</td>
<td>798.92</td>
<td>34</td>
<td>55,720</td>
</tr>
<tr>
<td>8</td>
<td>HSR 0.3 price, change frequency before HSR enters the market</td>
<td>2,047.36</td>
<td>102.55</td>
<td>593.37</td>
<td>43</td>
<td>33,664</td>
</tr>
<tr>
<td>9</td>
<td>HSR 0.3 price, change frequency before HSR enters the market, airport charge -40%, airlines keep the saving</td>
<td>2,250.25</td>
<td>86.40</td>
<td>626.25</td>
<td>50</td>
<td>33,846</td>
</tr>
<tr>
<td>10</td>
<td>HSR 0.3 price, change frequency and aircraft, before HSR enter the market, airport charge -40%, airlines pass it onto passengers</td>
<td>2,047.36</td>
<td>79.32</td>
<td>616.60</td>
<td>43</td>
<td>34,983</td>
</tr>
</tbody>
</table>
### Table A6.8 Impact on the Number of Passengers by Routes of Airline Response after HSR Entry (1,000’s pax)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
</tr>
<tr>
<td>1</td>
<td>12,600</td>
<td>0%</td>
<td>5,040</td>
<td>0%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>2</td>
<td>12,600</td>
<td>0%</td>
<td>5,040</td>
<td>0%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>3</td>
<td>6,174</td>
<td>-51%</td>
<td>2,830</td>
<td>-44%</td>
<td>1,842</td>
<td>-36%</td>
<td>1,440</td>
</tr>
<tr>
<td>4</td>
<td>8,070</td>
<td>-36%</td>
<td>3,093</td>
<td>-39%</td>
<td>2,282</td>
<td>-21%</td>
<td>1,440</td>
</tr>
<tr>
<td>5</td>
<td>8,540</td>
<td>-32%</td>
<td>3,806</td>
<td>-24%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>6</td>
<td>9,108</td>
<td>-28%</td>
<td>4,032</td>
<td>-20%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
</tbody>
</table>

* Compared to the baseline (case 1)

### Table A6.9 Impact on the Number of Flights by Routes of Airline Response after HSR Entry

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
<td>Flights</td>
</tr>
<tr>
<td>1</td>
<td>12,600</td>
<td>0%</td>
<td>5,040</td>
<td>0%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>2</td>
<td>12,600</td>
<td>0%</td>
<td>5,040</td>
<td>0%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>3</td>
<td>6,174</td>
<td>-51%</td>
<td>2,830</td>
<td>-44%</td>
<td>1,842</td>
<td>-36%</td>
<td>1,440</td>
</tr>
<tr>
<td>4</td>
<td>8,070</td>
<td>-36%</td>
<td>3,093</td>
<td>-39%</td>
<td>2,282</td>
<td>-21%</td>
<td>1,440</td>
</tr>
<tr>
<td>5</td>
<td>8,540</td>
<td>-32%</td>
<td>3,806</td>
<td>-24%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
<tr>
<td>6</td>
<td>9,108</td>
<td>-28%</td>
<td>4,032</td>
<td>-20%</td>
<td>2,880</td>
<td>0%</td>
<td>1,440</td>
</tr>
</tbody>
</table>

### Table A6.10 Impact on the Airport Revenues by Routes of Airline Response after HSR Entry (million ¥)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airport revenue</td>
<td>Airport revenue</td>
<td>Airport revenue</td>
<td>Airport revenue</td>
<td>Airport revenue</td>
<td>Airport revenue</td>
<td>Airport revenue</td>
</tr>
<tr>
<td>1</td>
<td>80.67</td>
<td>0%</td>
<td>32.04</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2</td>
<td>46.56</td>
<td>-42%</td>
<td>18.09</td>
<td>-44%</td>
<td>-31%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>3</td>
<td>35.04</td>
<td>-57%</td>
<td>16.08</td>
<td>-50%</td>
<td>-31%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>4</td>
<td>47.73</td>
<td>-41%</td>
<td>19.66</td>
<td>-39%</td>
<td>-28%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>5</td>
<td>50.64</td>
<td>-37%</td>
<td>21.88</td>
<td>-32%</td>
<td>-19%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>6</td>
<td>53.74</td>
<td>-33%</td>
<td>23.61</td>
<td>-26%</td>
<td>-1%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>

* Compared to the baseline (case 1)
Table A6.11 Impact on Airline Revenues* by Routes of Airline Response after HSR Entry (million ¥)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airline revenue</td>
<td>% change</td>
<td>Airline revenue</td>
<td>%</td>
<td>Airline revenue</td>
<td>%</td>
<td>Airline revenue</td>
</tr>
<tr>
<td>1</td>
<td>1,105.66</td>
<td>0%</td>
<td>360.14</td>
<td>0%</td>
<td>164.18</td>
<td>0%</td>
<td>195.83</td>
</tr>
<tr>
<td>2</td>
<td>557.19</td>
<td>-50%</td>
<td>135.48</td>
<td>-62%</td>
<td>102.97</td>
<td>-37%</td>
<td>77.79</td>
</tr>
<tr>
<td>3</td>
<td>470.27</td>
<td>-57%</td>
<td>176.93</td>
<td>-51%</td>
<td>103.57</td>
<td>-37%</td>
<td>24.58</td>
</tr>
<tr>
<td>4</td>
<td>475.56</td>
<td>-57%</td>
<td>162.04</td>
<td>-55%</td>
<td>96.03</td>
<td>-42%</td>
<td>30.44</td>
</tr>
<tr>
<td>5</td>
<td>412.92</td>
<td>-63%</td>
<td>143.49</td>
<td>-60%</td>
<td>85.38</td>
<td>-48%</td>
<td>59.20</td>
</tr>
<tr>
<td>6</td>
<td>338.77</td>
<td>-69%</td>
<td>118.87</td>
<td>-67%</td>
<td>70.73</td>
<td>-57%</td>
<td>49.26</td>
</tr>
</tbody>
</table>

*In this thesis, airline revenue = airline revenues from tickets sale – airport charges paid to the airport.

Table A6.12 Impact on the Number of Passengers by Routes of Airline Response before HSR Entry (1,000's pax)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pax</td>
<td>% change</td>
<td>pax</td>
<td>%</td>
<td>pax</td>
<td>%</td>
<td>pax</td>
</tr>
<tr>
<td>1</td>
<td>1,636.44</td>
<td>0%</td>
<td>647.21</td>
<td>0%</td>
<td>319.46</td>
<td>0%</td>
<td>292.86</td>
</tr>
<tr>
<td>2</td>
<td>1,133.59</td>
<td>-31%</td>
<td>581.85</td>
<td>-10%</td>
<td>396.89</td>
<td>24%</td>
<td>153.71</td>
</tr>
<tr>
<td>3</td>
<td>1,752.13</td>
<td>7%</td>
<td>868.57</td>
<td>34%</td>
<td>617.80</td>
<td>93%</td>
<td>246.88</td>
</tr>
<tr>
<td>4</td>
<td>3,087.20</td>
<td>89%</td>
<td>1,497.02</td>
<td>131%</td>
<td>1,064.35</td>
<td>233%</td>
<td>459.98</td>
</tr>
</tbody>
</table>

Table A6.13 Impact on the Number of Flights by Routes of Airline Response before HSR Entry

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>flight</td>
<td>% change</td>
<td>flight</td>
<td>% change</td>
<td>flight</td>
<td>% change</td>
<td>flight</td>
</tr>
<tr>
<td>1</td>
<td>12,600</td>
<td>0%</td>
<td>5,040</td>
<td>0%</td>
<td>2,880</td>
<td>0%</td>
<td>2,160</td>
</tr>
<tr>
<td>2</td>
<td>10,194</td>
<td>-19%</td>
<td>5,040</td>
<td>0%</td>
<td>3,418</td>
<td>19%</td>
<td>1,237</td>
</tr>
<tr>
<td>3</td>
<td>13,138</td>
<td>4%</td>
<td>6,535</td>
<td>30%</td>
<td>5,104</td>
<td>77%</td>
<td>2,006</td>
</tr>
<tr>
<td>4</td>
<td>22,622</td>
<td>80%</td>
<td>10,770</td>
<td>114%</td>
<td>8,606</td>
<td>199%</td>
<td>3,358</td>
</tr>
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</table>
Table A6.14 Impact on the Airport Revenues by Routes of Airline Response before HSR Entry (million ¥)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airport revenue</td>
<td>% change</td>
<td>Airport revenue</td>
<td>%</td>
<td>Airport revenue</td>
<td>%</td>
<td>Airport revenue</td>
</tr>
<tr>
<td>1</td>
<td>80.67</td>
<td>0%</td>
<td>32.04</td>
<td>0%</td>
<td>15.98</td>
<td>0%</td>
<td>4.39</td>
</tr>
<tr>
<td>2</td>
<td>57.18</td>
<td>-29%</td>
<td>29.26</td>
<td>-9%</td>
<td>19.72</td>
<td>23%</td>
<td>7.67</td>
</tr>
<tr>
<td>3</td>
<td>86.06</td>
<td>7%</td>
<td>42.80</td>
<td>34%</td>
<td>30.52</td>
<td>91%</td>
<td>12.34</td>
</tr>
<tr>
<td>4</td>
<td>151.18</td>
<td>87%</td>
<td>73.30</td>
<td>129%</td>
<td>52.42</td>
<td>228%</td>
<td>22.63</td>
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Table A6.15 Impact on the Airline Revenues* by Routes of Airline Response before HSR Entry (million ¥)

<table>
<thead>
<tr>
<th>Case</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
<th>Wenzhou</th>
<th>Wuhan</th>
<th>Jinan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airline revenue</td>
<td>% change</td>
<td>Airline revenue</td>
<td>%</td>
<td>Airline revenue</td>
<td>%</td>
<td>Airline revenue</td>
</tr>
<tr>
<td>1</td>
<td>1,105.66</td>
<td>0%</td>
<td>360.14</td>
<td>0%</td>
<td>164.18</td>
<td>0%</td>
<td>195.83</td>
</tr>
<tr>
<td>2</td>
<td>543.84</td>
<td>-51%</td>
<td>228.25</td>
<td>-37%</td>
<td>143.42</td>
<td>-13%</td>
<td>73.40</td>
</tr>
<tr>
<td>3</td>
<td>665.56</td>
<td>-40%</td>
<td>268.68</td>
<td>-25%</td>
<td>175.18</td>
<td>7%</td>
<td>93.03</td>
</tr>
<tr>
<td>4</td>
<td>856.07</td>
<td>-23%</td>
<td>336.21</td>
<td>-7%</td>
<td>218.22</td>
<td>33%</td>
<td>126.52</td>
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</table>

Table A6.16 Analysis of Impacts at the Airline Level on the Route Nanjing-Qingdao

<table>
<thead>
<tr>
<th>Case</th>
<th>Number of Passengers (1,000 pax)</th>
<th>Number of Flights</th>
<th>Airport revenues (million ¥)</th>
<th>Airline revenues (million ¥)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MU</td>
<td>SC</td>
<td>MU</td>
<td>SC</td>
</tr>
<tr>
<td>1</td>
<td>151.73</td>
<td>159.08</td>
<td>1,440</td>
<td>1,440</td>
</tr>
<tr>
<td>2</td>
<td>95.98</td>
<td>152.31</td>
<td>1,440</td>
<td>1,440</td>
</tr>
<tr>
<td>3</td>
<td>122.73</td>
<td>224.08</td>
<td>1,103</td>
<td>2,016</td>
</tr>
<tr>
<td>4</td>
<td>122.73</td>
<td>224.08</td>
<td>1,103</td>
<td>2,016</td>
</tr>
<tr>
<td>5</td>
<td>123.03</td>
<td>224.99</td>
<td>1,103</td>
<td>2,016</td>
</tr>
<tr>
<td>6</td>
<td>122.73</td>
<td>224.08</td>
<td>1,103</td>
<td>2,016</td>
</tr>
</tbody>
</table>

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### A7 Results in Chapter 7

Table A7.1 Comparison of Impact on Airport for Nine Routes before and after LCC Entry with FSA Fares Unchanged

<table>
<thead>
<tr>
<th>Route price elasticity</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before LCC entry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route price elasticity</td>
<td>-1.15</td>
<td>-1.4</td>
<td>-1.15</td>
<td>-1.15</td>
<td>-1.16</td>
<td>-1.16</td>
<td>-1.16</td>
<td>-1.15</td>
<td>-1.14</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>417.888</td>
<td>581.496</td>
<td>1,310.039</td>
<td>552.133</td>
<td>359.397</td>
<td>1,784.653</td>
<td>862.543</td>
<td>269.911</td>
<td>180.341</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>20.974</td>
<td>28.680</td>
<td>64.985</td>
<td>27.455</td>
<td>17.959</td>
<td>87.695</td>
<td>43.084</td>
<td>13.375</td>
<td>8.938</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>413.609</td>
<td>287.043</td>
<td>1,224.027</td>
<td>546.736</td>
<td>403.595</td>
<td>1,418.462</td>
<td>745.237</td>
<td>341.005</td>
<td>269.499</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>3,600</td>
<td>4,320</td>
<td>9,360</td>
<td>4,320</td>
<td>2,880</td>
<td>12,960</td>
<td>7,200</td>
<td>2,160</td>
<td>1,440</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Route price elasticity</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td>After LCC entry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Route price elasticity</td>
<td>-1.15</td>
<td>-1.4</td>
<td>-1.15</td>
<td>-1.15</td>
<td>-1.16</td>
<td>-1.16</td>
<td>-1.16</td>
<td>-1.15</td>
<td>-1.14</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>438.492</td>
<td>607.275</td>
<td>1,331.772</td>
<td>573.784</td>
<td>380.313</td>
<td>1,811.766</td>
<td>887.393</td>
<td>291.766</td>
<td>198.661</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>22.140</td>
<td>30.065</td>
<td>66.199</td>
<td>28.689</td>
<td>19.161</td>
<td>89.160</td>
<td>44.431</td>
<td>14.617</td>
<td>10.030</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>413.539</td>
<td>288.963</td>
<td>1,224.624</td>
<td>546.903</td>
<td>403.346</td>
<td>1,420.762</td>
<td>747.527</td>
<td>341.068</td>
<td>267.975</td>
</tr>
<tr>
<td>Total FSA revenue</td>
<td>387.859</td>
<td>276.163</td>
<td>1,199.975</td>
<td>520.245</td>
<td>373.386</td>
<td>1,396.909</td>
<td>723.601</td>
<td>306.073</td>
<td>231.076</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>3,940</td>
<td>4,660</td>
<td>9,700</td>
<td>4,660</td>
<td>3,220</td>
<td>13,300</td>
<td>7,540</td>
<td>2,500</td>
<td>1,780</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Route price elasticity</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td>% change</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax</td>
<td>4.93%</td>
<td>4.43%</td>
<td>1.66%</td>
<td>3.92%</td>
<td>5.82%</td>
<td>1.52%</td>
<td>2.88%</td>
<td>8.10%</td>
<td>10.16%</td>
</tr>
<tr>
<td>Total airport revenue</td>
<td>5.56%</td>
<td>4.83%</td>
<td>1.87%</td>
<td>4.49%</td>
<td>6.69%</td>
<td>1.67%</td>
<td>3.12%</td>
<td>9.29%</td>
<td>12.22%</td>
</tr>
<tr>
<td>Total airline revenue</td>
<td>-0.02%</td>
<td>0.67%</td>
<td>0.05%</td>
<td>0.03%</td>
<td>-0.06%</td>
<td>0.16%</td>
<td>0.31%</td>
<td>0.02%</td>
<td>-0.57%</td>
</tr>
<tr>
<td>Total FSA revenue</td>
<td>-6.23%</td>
<td>-3.79%</td>
<td>-1.97%</td>
<td>-4.85%</td>
<td>-7.48%</td>
<td>-1.52%</td>
<td>-2.90%</td>
<td>-10.24%</td>
<td>-14.26%</td>
</tr>
<tr>
<td>Total flight</td>
<td>9.44%</td>
<td>7.87%</td>
<td>3.63%</td>
<td>7.87%</td>
<td>11.81%</td>
<td>2.62%</td>
<td>4.72%</td>
<td>15.74%</td>
<td>23.61%</td>
</tr>
<tr>
<td>Market share LCCs (%)</td>
<td>11.1</td>
<td>8.2</td>
<td>3.7</td>
<td>8.8</td>
<td>13.1</td>
<td>3.1</td>
<td>5.9</td>
<td>17.7</td>
<td>23.1</td>
</tr>
</tbody>
</table>
Table A7.2 Comparison of Impact on Airport for Nine Routes with LCC When FSA Fares Decrease

<table>
<thead>
<tr>
<th>Route</th>
<th>After LCC entry with FSA airfare unchanged</th>
<th>After LCC entry with FSA airfare decreased by 2.3%</th>
<th>After LCC entry with FSA airfare decreased by 6.2%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total airport pax (1000’s pax)</td>
<td>Total airport pax change %</td>
<td>Total airport pax change %</td>
</tr>
<tr>
<td></td>
<td>438.492</td>
<td>445.130</td>
<td>456.463</td>
</tr>
<tr>
<td></td>
<td>607.275</td>
<td>618.805</td>
<td>636.894</td>
</tr>
<tr>
<td>Shenyang</td>
<td>1,331.772</td>
<td>1,353.530</td>
<td>1,390.047</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>573.784</td>
<td>582.693</td>
<td>597.883</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>380.313</td>
<td>385.934</td>
<td>395.545</td>
</tr>
<tr>
<td>Changchun</td>
<td>1,811.766</td>
<td>1,837.791</td>
<td>1,876.129</td>
</tr>
<tr>
<td>Harbin</td>
<td>887.393</td>
<td>899.871</td>
<td>918.333</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>291.76</td>
<td>302.846</td>
<td>337.897</td>
</tr>
<tr>
<td>Chongqing</td>
<td>6198.661</td>
<td>636.894</td>
<td>265.659</td>
</tr>
<tr>
<td>Haikou</td>
<td>198.661</td>
<td>201.253</td>
<td>168.22</td>
</tr>
<tr>
<td>Hailar</td>
<td>198.661</td>
<td>201.253</td>
<td>168.22</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue (million ¥)</td>
<td>Total airport revenue change %</td>
<td>Total airport revenue change %</td>
</tr>
<tr>
<td></td>
<td>22.140</td>
<td>22.422</td>
<td>22.903</td>
</tr>
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<td></td>
<td>30.065</td>
<td>30.555</td>
<td>31.323</td>
</tr>
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<td>66.199</td>
<td>67.123</td>
<td>68.673</td>
</tr>
<tr>
<td></td>
<td>28.689</td>
<td>29.067</td>
<td>29.712</td>
</tr>
<tr>
<td></td>
<td>19.161</td>
<td>19.400</td>
<td>19.808</td>
</tr>
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<td></td>
<td>89.160</td>
<td>91.893</td>
<td>91.893</td>
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<td></td>
<td>44.431</td>
<td>45.744</td>
<td>45.744</td>
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<td>14.617</td>
<td>15.087</td>
<td>15.087</td>
</tr>
<tr>
<td></td>
<td>10.030</td>
<td>10.141</td>
<td>10.141</td>
</tr>
<tr>
<td></td>
<td>Total airline revenues (million ¥)</td>
<td>Total airline revenues change %</td>
<td>Total airline revenues change %</td>
</tr>
<tr>
<td></td>
<td>413.539</td>
<td>412.207</td>
<td>409.320</td>
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<td>288.963</td>
<td>288.824</td>
<td>287.309</td>
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<td>1,224.624</td>
<td>1,220.346</td>
<td>1,210.572</td>
</tr>
<tr>
<td></td>
<td>546.903</td>
<td>545.109</td>
<td>541.202</td>
</tr>
<tr>
<td></td>
<td>403.346</td>
<td>402.087</td>
<td>399.367</td>
</tr>
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<td></td>
<td>1,420.762</td>
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<td>1,392.601</td>
</tr>
<tr>
<td></td>
<td>747.527</td>
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<td>733.392</td>
</tr>
<tr>
<td></td>
<td>341.068</td>
<td>337.897</td>
<td>337.897</td>
</tr>
<tr>
<td></td>
<td>267.975</td>
<td>265.659</td>
<td>265.659</td>
</tr>
<tr>
<td></td>
<td>Total annual flight (flights)</td>
<td>Total annual flight change %</td>
<td>Total annual flight change %</td>
</tr>
<tr>
<td></td>
<td>3,940</td>
<td>3,940</td>
<td>3,940</td>
</tr>
<tr>
<td></td>
<td>4,660</td>
<td>4,660</td>
<td>4,660</td>
</tr>
<tr>
<td></td>
<td>9,700</td>
<td>9,700</td>
<td>9,700</td>
</tr>
<tr>
<td></td>
<td>4,660</td>
<td>4,660</td>
<td>4,660</td>
</tr>
<tr>
<td></td>
<td>3,220</td>
<td>3,220</td>
<td>3,220</td>
</tr>
<tr>
<td></td>
<td>13,300</td>
<td>13,300</td>
<td>13,300</td>
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<tr>
<td></td>
<td>7,540</td>
<td>7,540</td>
<td>7,540</td>
</tr>
<tr>
<td></td>
<td>2,500</td>
<td>2,500</td>
<td>2,500</td>
</tr>
<tr>
<td></td>
<td>1,780</td>
<td>1,780</td>
<td>1,780</td>
</tr>
<tr>
<td></td>
<td>Market share LCCs (%)</td>
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</tr>
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<td>10.9</td>
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<td>8.0</td>
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<tr>
<td></td>
<td>3.6</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>8.6</td>
<td>8.6</td>
<td>8.3</td>
</tr>
<tr>
<td></td>
<td>12.9</td>
<td>12.9</td>
<td>12.4</td>
</tr>
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<td></td>
<td>3.1</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
<td>5.8</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>17.4</td>
<td>17.4</td>
<td>16.8</td>
</tr>
<tr>
<td></td>
<td>22.7</td>
<td>22.7</td>
<td>22.7</td>
</tr>
</tbody>
</table>

Table A7.3 Changes in Airport Passengers and Revenue (%) When FSA Fares Decrease

<table>
<thead>
<tr>
<th>Route</th>
<th>After LCC entry with FSA airfare decreased by 2.3% compared with airfare unchanged</th>
<th>After LCC entry with FSA airfare decreased by 6.2% compared with airfare unchanged</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total airport pax change %</td>
<td>Total airport pax change %</td>
</tr>
<tr>
<td>Shenyang</td>
<td>1.51%</td>
<td>4.10%</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>1.90%</td>
<td>4.88%</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>1.63%</td>
<td>4.38%</td>
</tr>
<tr>
<td>Changchun</td>
<td>1.55%</td>
<td>4.20%</td>
</tr>
<tr>
<td>Harbin</td>
<td>1.48%</td>
<td>4.01%</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>1.44%</td>
<td>3.55%</td>
</tr>
<tr>
<td>Chongqing</td>
<td>1.41%</td>
<td>3.49%</td>
</tr>
<tr>
<td>Haikou</td>
<td>1.40%</td>
<td>3.80%</td>
</tr>
<tr>
<td>Hailar</td>
<td>1.30%</td>
<td>3.55%</td>
</tr>
<tr>
<td></td>
<td>Total airport revenue change %</td>
<td>Total airport revenue change %</td>
</tr>
<tr>
<td>Shenyang</td>
<td>1.27%</td>
<td>3.45%</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>1.63%</td>
<td>4.18%</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>1.40%</td>
<td>3.74%</td>
</tr>
<tr>
<td>Changchun</td>
<td>1.32%</td>
<td>3.57%</td>
</tr>
<tr>
<td>Harbin</td>
<td>1.25%</td>
<td>3.37%</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>1.24%</td>
<td>3.06%</td>
</tr>
<tr>
<td>Chongqing</td>
<td>1.19%</td>
<td>2.96%</td>
</tr>
<tr>
<td>Haikou</td>
<td>1.19%</td>
<td>2.22%</td>
</tr>
<tr>
<td>Hailar</td>
<td>1.10%</td>
<td>2.98%</td>
</tr>
<tr>
<td></td>
<td>Total airline revenues change %</td>
<td>Total airline revenues change %</td>
</tr>
<tr>
<td>Shenyang</td>
<td>-0.32%</td>
<td>-1.02%</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>-0.05%</td>
<td>-0.57%</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>-0.35%</td>
<td>-1.15%</td>
</tr>
<tr>
<td>Changchun</td>
<td>-0.33%</td>
<td>-1.04%</td>
</tr>
<tr>
<td>Harbin</td>
<td>-0.31%</td>
<td>-0.99%</td>
</tr>
<tr>
<td>Guangzhou</td>
<td>-0.56%</td>
<td>-1.98%</td>
</tr>
<tr>
<td>Chongqing</td>
<td>-0.54%</td>
<td>-1.89%</td>
</tr>
<tr>
<td>Haikou</td>
<td>-0.30%</td>
<td>-0.93%</td>
</tr>
<tr>
<td>Hailar</td>
<td>-0.28%</td>
<td>-0.86%</td>
</tr>
</tbody>
</table>
Table A7.4 Changes in Airline (FSA and LCC) Passenger Volume (%)

<table>
<thead>
<tr>
<th>City</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare unchanged compared with before LCC (%)</td>
<td>-6.7</td>
<td>-4.1</td>
<td>-2.1</td>
<td>-5.2</td>
<td>-8.1</td>
<td>-1.7</td>
<td>-3.2</td>
<td>-11.1</td>
<td>-15.3</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare decreased by 2.3% compared with airfare unchanged (%)</td>
<td>1.8</td>
<td>-0.6</td>
<td>2.1</td>
<td>-0.3</td>
<td>1.7</td>
<td>-0.6</td>
<td>1.8</td>
<td>-0.6</td>
<td>1.5</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare decreased by 6.2% compared with airfare unchanged (%)</td>
<td>4.8</td>
<td>-1.7</td>
<td>5.4</td>
<td>-1.1</td>
<td>4.6</td>
<td>-1.9</td>
<td>4.8</td>
<td>-1.7</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Table A7.5 Changes in Airline (FSA and LCC) revenue (%)

<table>
<thead>
<tr>
<th>City</th>
<th>Shenyang</th>
<th>Fuzhou</th>
<th>Shenzhen</th>
<th>Changchun</th>
<th>Harbin</th>
<th>Guangzhou</th>
<th>Chongqing</th>
<th>Haikou</th>
<th>Hailar</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
<td>LCC</td>
<td>FSA</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare unchanged compared with before LCC (%)</td>
<td>-6.2</td>
<td>-3.8</td>
<td>-2</td>
<td>-4.8</td>
<td>-7.5</td>
<td>-1.5</td>
<td>-2.9</td>
<td>-10.2</td>
<td>-14.2</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare decreased by 2.3% compared with airfare unchanged (%)</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.1</td>
<td>-0.4</td>
<td>-0.3</td>
<td>-0.3</td>
<td>-0.5</td>
<td>-0.5</td>
<td>-0.3</td>
</tr>
<tr>
<td>After LCC entry with FSA airfare decreased by 6.2% compared with airfare unchanged (%)</td>
<td>-1.0</td>
<td>-0.9</td>
<td>-0.6</td>
<td>-0.3</td>
<td>-1.1</td>
<td>-1.0</td>
<td>-0.9</td>
<td>-0.9</td>
<td>-0.9</td>
</tr>
</tbody>
</table>
Table A7.6 Comparison of Airport and Airline Revenues, before and after HSR Entry, in the Presence of LCC

<table>
<thead>
<tr>
<th>Market share FSA (%)</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1 - Without HSR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax (1,000’s pax)</td>
<td>1,783.171</td>
<td>641.088</td>
<td>311.837</td>
<td>300.038</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>12,600</td>
<td>5,040</td>
<td>2,880</td>
<td>2,160</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>88.082</td>
<td>31.778</td>
<td>15.659</td>
<td>14.734</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>1,176.934</td>
<td>327.975</td>
<td>104.466</td>
<td>123.762</td>
</tr>
<tr>
<td>Case 2 - With HSR, airfare no change</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax (1,000’s pax)</td>
<td>926.612</td>
<td>364.853</td>
<td>247.615</td>
<td>157.003</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>8,097</td>
<td>3,170</td>
<td>2,227</td>
<td>1,292</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>47.271</td>
<td>18.364</td>
<td>12.373</td>
<td>7.859</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>603.843</td>
<td>175.325</td>
<td>75.125</td>
<td>52.151</td>
</tr>
<tr>
<td>% change (compare with Case 1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax (1,000’s pax)</td>
<td>-48%</td>
<td>-43%</td>
<td>-21%</td>
<td>-48%</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>-36%</td>
<td>-37%</td>
<td>-23%</td>
<td>-40%</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>-46%</td>
<td>-42%</td>
<td>-21%</td>
<td>-47%</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>-49%</td>
<td>-47%</td>
<td>-28%</td>
<td>-58%</td>
</tr>
<tr>
<td>Case 3 - With HSR, airfare changed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total airport pax (1,000’s pax)</td>
<td>1,065.784</td>
<td>449.995</td>
<td>308.420</td>
<td>186.832</td>
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<tr>
<td>Total annual flight (flights)</td>
<td>9,024</td>
<td>3,480</td>
<td>2,783</td>
<td>1,583</td>
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<tr>
<td>Total airport revenue (million ¥)</td>
<td>54.089</td>
<td>22.265</td>
<td>15.422</td>
<td>9.395</td>
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<tr>
<td>Total airline revenue (million ¥)</td>
<td>514.134</td>
<td>162.922</td>
<td>72.251</td>
<td>53.103</td>
</tr>
<tr>
<td>% change (compare with Case 2)</td>
<td></td>
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<td></td>
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<tr>
<td>Total airport pax (1,000’s pax)</td>
<td>15%</td>
<td>23%</td>
<td>25%</td>
<td>19%</td>
</tr>
<tr>
<td>Total annual flight (flights)</td>
<td>11%</td>
<td>10%</td>
<td>25%</td>
<td>23%</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>14%</td>
<td>21%</td>
<td>25%</td>
<td>20%</td>
</tr>
<tr>
<td>Total airline revenue (million ¥)</td>
<td>-15%</td>
<td>-7%</td>
<td>-4%</td>
<td>2%</td>
</tr>
<tr>
<td>Case 1 - Without HSR</td>
<td>Beijing</td>
<td>Changsha</td>
<td>Qingdao</td>
<td>Tianjin</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------</td>
<td>----------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>1,700.083</td>
<td>83.089</td>
<td>534.261</td>
<td>106.828</td>
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<tr>
<td>Total annual flight (flight)</td>
<td>11,880</td>
<td>720</td>
<td>4,320</td>
<td>720</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>1,148.514</td>
<td>28.421</td>
<td>297.158</td>
<td>30.816</td>
</tr>
<tr>
<td>% change (compare with Case 1)</td>
<td>-49%</td>
<td>-25%</td>
<td>-51%</td>
<td>-4.60%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case 2 - With HSR, airfare no change</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>864.703</td>
<td>61.909</td>
<td>262.945</td>
<td>101.909</td>
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<tr>
<td>Total annual flight (flight)</td>
<td>7,377</td>
<td>720</td>
<td>2450</td>
<td>720</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>582.818</td>
<td>21.025</td>
<td>145.959</td>
<td>29.367</td>
</tr>
<tr>
<td>% change (compare with Case 1)</td>
<td>-48%</td>
<td>-22%</td>
<td>-50%</td>
<td>-4.02%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Case 3 - With HSR, airfare no change</th>
<th>Beijing</th>
<th>Changsha</th>
<th>Qingdao</th>
<th>Tianjin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total airport pax (1000’s pax)</td>
<td>992.056</td>
<td>73.728</td>
<td>326.153</td>
<td>123.843</td>
</tr>
<tr>
<td>Total annual flight (flight)</td>
<td>8,304</td>
<td>720</td>
<td>2474</td>
<td>1,006</td>
</tr>
<tr>
<td>Total airport revenue (million ¥)</td>
<td>493.076</td>
<td>21.059</td>
<td>162.922</td>
<td>29.731</td>
</tr>
<tr>
<td>% change (compare with case 3 and case 1)</td>
<td>-49%</td>
<td>-25%</td>
<td>-51%</td>
<td>-4.60%</td>
</tr>
</tbody>
</table>

% change (compare with case 3 and case 2)

| Total airport pax (1000’s pax) | 15% | 19% | 24% | 22% |
| Total annual flight (flight) | 13% | 0% | 1% | 40% |
| Total airport revenue (million ¥) | 14% | 16% | 20% | 24% |