

## Asymmetric Duopoly in Space – what policies work?

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ERSA Congress Amsterdam 2005

### Abstract

In this paper we study the problem of a city with access to two subcentres selling a differentiated product. The first subcentre has low free flow transport costs but is easily congested (near city centre, access by road). The second one has higher free flow transport costs but is less prone to congestion (ample public transport capacity, parking etc.). Both subcentres need to attract customers and employees by offering prices and wages that are sufficiently attractive to cover their fixed costs. In the absence of any government regulation, there will be an asymmetric duopoly game that can be solved for a Nash equilibrium in prices and wages offered by the two subcentres. This solution is typically characterised by excessive congestion for the nearby subcentre. We study the welfare effects of a number of stylised policies using competition between airports as an example.

The first policy is to extend the road to subcentre 1. This policy will not necessarily lead to less congestion as more customers will be attracted by the lower transport costs. The second policy option is to add congestion pricing (or parking pricing etc.) for the congested subcentre. This will decrease its profit margin and attract more customers. The third policy is acceptable for politicians: investing providing a direct subsidy to the remote subcentre, reducing its marginal costs. This policy will again ease the congestion problem for the nearby subcentre but will do this in a very costly way. Finally an additional remote subcentre can be added to the model set-up.

**Keywords:** duopoly, imperfect competition, congestion

**JEL-classification:** L13, D43, R41, R13

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<sup>1</sup> We wish to acknowledge the support of DWTC, Belgium (Project CP-01-401)

# Asymmetric Duopoly in Space – what policies work?

## 1. INTRODUCTION

In this paper we study the problem of a city that has access to two facilities (e.g shopping centres, airports) selling a differentiated product. The first subcentre has low transport costs but is easily congested (near city centre, access by road). The second one has higher transport costs but is less prone to congested access (ample public transport capacity etc.). Both subcentres need to attract customers and employees by offering prices and wages that are sufficiently attractive to cover their fixed costs. The equilibrium is the outcome of the interplay between endogenous congestion and market forces. In the absence of any government regulation, there will be an asymmetric monopolistic competition game that can be solved for a Nash equilibrium in prices and wages offered by each of the two subcentres. This solution is typically characterised by excessive congestion for the nearby subcentre. We study the welfare effects of a number of stylised policies.

The first policy is to extend the road to the nearby facility, subcentre 1. Interestingly, this policy will not necessarily lead to less congestion as more customers will be attracted by the lower transport costs. This is close to the well known Braess paradox in transport economics. In our paper we add product and labour differentiation and it will be the degrees of differentiation that will determine how successful the road extension strategy is. The second policy is to add congestion pricing (or parking pricing etc.) for the congested subcentre. This will decrease its profit margin (see de Palma & Proost, 2005) and attract more customers. The third policy is more acceptable for politicians: providing a direct subsidy to the remote subcentre, reducing its marginal costs. This policy will again ease the congestion problem for the nearby subcentre but will do this in a very costly way. Finally an additional remote subcentre is added to the model set-up.

We apply our model to airports, using Brussels International Airport (Zaventem) and Charleroi -Brussels South (Charleroi) to illustrate the effect of the above policy options. Increasingly cities in Europe are served by two (or more) airports, which offer differentiated products in terms of quality and frequency of flights but also differ in their facilities and accessibility. A sizable literature exists on airport competition (see for example Hansen et al. (2001), Barrett (2004) and Veldhuis (2004)). Ivaldi and Vibes (2004) have looked at oligopolistic price competition between traditional and low cost airlines and rail using a game theoretic approach. In this paper we use a general equilibrium approach so that wages are also modelled.

The theoretical framework of the model is described in Section 2, the existing market equilibrium for the airport application is developed in Section 3 and the effects of our policy options are considered. Section 4 concludes.

## 2. THEORETICAL FRAMEWORK

### 2.1. Model Setting

de Palma and Proost (2005) have developed a model to study imperfect competition in a city both with and without congestion. Although they concentrate their analysis on the symmetric situation, the basic model set-up also applies in the more general asymmetric case. A brief description of the model setting is therefore presented here together with the relevant equations for household preferences and firms' profits in an asymmetric oligopoly with congested transport infrastructure. A simple, asymmetric duopoly is then used to illustrate the effects of various policy scenarios in Chapter 3.

Residents live in a city centre and travel to one of two sub-centres to work and shop. Shopping and working decisions are made independently, so that trip chaining is excluded, and residents can only travel between the centre and each subcentre and not between subcentres (see [Figure 2-1](#))<sup>2</sup>. A homogeneous good is produced in the city centre and used as an intermediate input for the differentiated good, which is produced in the sub-centres. Thus, both firms and consumers incur travel costs. In this general equilibrium setting, the numéraire homogeneous good represents all production in the economy other than the differentiated good and all profits are returned to the households. The labour market is also considered separately and jobs in the differentiated industry are heterogeneous. Only one differentiated product variant is produced at each sub-centre by a single firm and each household will consume one unit of differentiated good and supply one unit of labour for its production. Hence, in the current formulation, demand for the differentiated good is inelastic and, if the labour market is assumed to be fully flexible, the product and labour markets will clear. All remaining labour ( $\theta$ ) and income is devoted to the homogeneous good and there is therefore no possibility of non-consumption or unemployment.

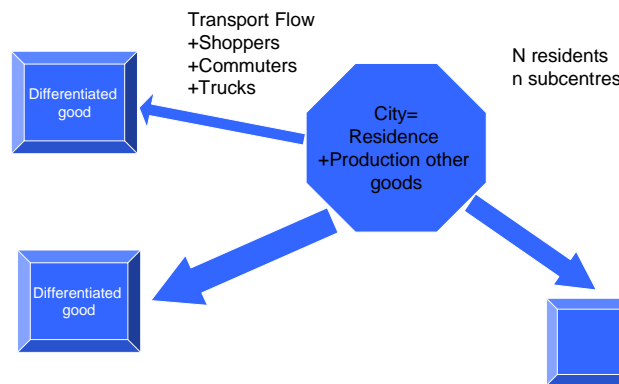


Figure 2-1 Schematic of city layout

<sup>2</sup> While trip chaining can clearly be important in the decision process for many households, it significantly complicates the modelling process and is presented in a separate paper (de Palma, et al. 2005). Here we focus on households who, for example, do a weekly shop as a family, independent of work commitments or on an airport trip where customers and the workforce represent different sections of the population.

The total production possibilities of an economy with  $N$  households and  $n$  firms can then be expressed in terms of the following identity for labour supply and demand:

$$(1 + \theta)N = D + c^1 D + \sum_{i=1}^n F_i + (\alpha^w + \alpha^d + \alpha^h) \sum_{i=1}^N t_i D_i + \sum_{i=1}^n K_i + G \quad (1)$$

where  $D (= \sum D_i)$  is the total demand for the differentiated good,  $c^1$  is the marginal production cost of the intermediate input,  $F_i$  is the fixed production cost for firm  $i$  and transportation costs for commuting, shopping and supply of goods are given by  $(\alpha^w + \alpha^d + \alpha^h) \sum_{i=1}^N t_i D_i$ <sup>3</sup>. The  $\alpha^w, \alpha^d, \alpha^h$  denote trip frequencies and the  $t_i$  travel times, which are exogenous when there is no congestion. Each sub-centre requires some road infrastructure ( $K_i$ ), which is paid for by a levy on firms and head-tax (T) on consumers. Finally, G denotes residual consumption of the homogeneous good.

## 2.2. Congestion

The main effect of congestion on the model is to make travel times endogenous. Instead of being constant, travel times increase with the number of road users, where the road users are customers, commuters and trucks delivering the intermediate input. de Palma and Proost assume that roads have a fixed capacity and that a bottleneck develops if the activity on a road exceeds its capacity. They use the bottleneck model developed by Arnott et al (1993), where road users choose their trip timing (with no congestion pricing). In the simplest case, where all agents have the same desired arrival times and the same valuation of time, we can define the endogenous travel time for the asymmetric model as

$$t_i = t_i^o + \delta \frac{N}{s_i} \alpha P_i^w \quad (2)$$

where  $\alpha = \alpha^d + \alpha^w + \kappa \alpha^h$  and  $\kappa$  ensures that one truck trip has the same congestion effect as  $\kappa$  shopping or commuting trips. In the absence of congestion  $t_i^o$  is the transport time from the centre to sub-centre  $i$  and  $s_i$  is the corresponding road capacity.

From (2) it can be seen that roads are free of congestion in the limit of infinite bottleneck capacity.<sup>4</sup> The coefficient  $\delta$  translates waiting time and schedule delays into equivalent costs.

## 2.3. Household Preferences

Household utility is represented by a linear function of the utility obtained from consumption of the differentiated and homogeneous goods and the disutility of

<sup>3</sup> Note that because wages and prices for the homogeneous good have been normalised to one, the value of time is also one.

<sup>4</sup> The non-congestion case is actually modelled separately using exogenous travel times;  $s$  is not used.

supplying labour to the production of these goods. Using the household budget equation to substitute for consumption of the homogeneous good, an indirect conditional utility function can be derived to express household preferences. In this case the utility function represents the preferences of a household that buys differentiated good  $k$  and supplies labour to sub-centre  $i$ :

$$U_{ik} = \tilde{h}_k - p_k - \alpha^d t_k + w_i - \tilde{\beta}_i - \alpha^w t_i + \theta(1 - \beta) + \frac{1}{N} \sum_l \pi_l - T \quad (3)$$

Each of the  $N$  households is paid a wage,  $w_i$ , for working at sub-centre  $i$  and buys one unit of variant  $k$  at price,  $p_k$ . Both prices and wages will be determined by the model. In the following we will use household and consumer interchangeably as it is easier to consider the household as a single worker or customer. Thus, the consumer's commuting and shopping travel costs are given by  $\alpha^w t_i$  and  $\alpha^d t_i$  respectively, where, from (2),  $t_i$  is endogenous. The utility of consumption of differentiated product variant  $k$  is given by an intrinsic quality component  $h_k$  and a stochastic component  $\mu^d \varepsilon_k$ :

$$\tilde{h}_k = h_k + \mu^d \varepsilon_k \quad (4)$$

and the disutility of labour at sub-centre  $i$  is similarly given by the following two components:

$$\tilde{\beta}_i = \beta_i - \mu^w \varepsilon_i \quad (5)$$

Hence, all households will value the quality of the product variant manufactured at a particular subcentre in the same way and will experience the same disinclination to work at a given subcentre; in both cases possibly assigning different values to different subcentres. However, the households will still vary in their tastes: the parameters  $\varepsilon_i$  and  $\varepsilon_k$  represent the intrinsic heterogeneity of consumer tastes and it is again assumed that they are double exponentially distributed. The parameters  $\mu^w$  and  $\mu^d$  determine the degree of heterogeneity of preferences.

The remaining terms in (3) represent a household's utility from production of the homogeneous good, share of the profits and the head-tax ( $T$ ). These are the same for all consumers.

When a household chooses where to work, this is independent of its shopping decision and vice versa because we rule out trip chaining. Substituting from (4) and (5) in (3), we obtain:

$$U_{ik} = \Omega_k + w_i - \beta_i - \alpha^w t_i + \mu^w \varepsilon_i,$$

where  $\Omega_k = \theta(1 - \beta) + \frac{1}{N} \sum_l \pi_l - T + h_k - p_k - \alpha^d t_k + \mu^d \varepsilon_k$  is assumed fixed for the

choice of employment location. The probability that a consumer chooses to commute to

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sub-centre  $i$  of the  $n$  possible sub-centres is then  $P_i^w = \text{Prob}\{U_{i|k} \geq U_{j|k} \forall j = 1, \dots, n\}$ , independent of  $k$  and can be written as a logit type probability

$$P_i^w = \frac{\exp\left(\frac{w_i - \beta_i - \alpha^w t_i}{\mu^w}\right)}{\sum_j \exp\left(\frac{w_j - \beta_j - \alpha^w t_j}{\mu^w}\right)}. \quad (6)$$

For the household choice of shopping location, we obtain

$$U_{k|i} = \Omega_i + h_k - p_k - \alpha^d t_k + \mu^d \varepsilon_k,$$

where  $\Omega_i = \theta(1 - \beta) + \frac{1}{N} \sum_t \pi_t - T + w_i - \beta_i - \alpha^w t_i + \mu^w \varepsilon_i$  is assumed constant for shopping decisions, and a similar expression for the probability is derived:

$$P_k^d = \frac{\exp\left(\frac{h_k - p_k - \alpha^d t_k}{\mu^d}\right)}{\sum_j \exp\left(\frac{h_j - p_j - \alpha^d t_j}{\mu^d}\right)} \quad (7)$$

Since travel times are endogenous (2), (6) and (7) are implicit equations in  $P_i^w$  and  $P_k^d$ . Even for the duopoly case, these equations cannot be solved analytically and a numerical solution is required for each given  $p$  and  $w$ .

Using the assumptions of inelastic demand for the differentiated good and fixed labour input for the differentiated good, a market clearing condition also applies at each sub-centre:

$$P_i^w = P_i^d \quad (8)$$

## 2.4. Profits of firms

There are  $n$  firms, each located at one of the subcentres. The profit of firm  $i$  is:

$$\pi_i(w, p) = (p_i - w_i - c^1 - \alpha^h t_i) D_i - (F_i + S_i) \quad (9)$$

where  $c^1 + \alpha^h t_i$  is the marginal cost of the intermediate input,  $F_i$  is the fixed production cost and  $S_i$  is the government levy to pay for public infrastructure. The inelastic demand condition gives us  $\sum_i^n D_i = N$  and from (8), we obtain demand  $D_i = NP_i^w = NP_i^d$ .

Each firm selects prices and wages to maximise his profits, given that his competitors do the same. Thus we look for a non-cooperative Nash equilibrium in these variables.

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## 2.5. Equilibrium

The strategic variables of firm  $i$  are  $w_i$  and  $p_i$ . From the market clearing condition (8), substituting from (6) and (7), it is clear that the choice of  $w_i$  determines the choice of  $p_i$  (and vice versa), since all other prices and wages are taken as given. Thus, we can rewrite the profit equation (9) as:

$$\pi_i(w_i) = (p_i[w_i] - w_i - c^1 - \alpha^h t_i^o) NP_i^w[w_i] - (F_i + S_i) \quad (10)$$

Thus, taking  $w_i$  as our only strategic variable, the best response of firm  $i$  is given by:

$$\frac{d\pi_i}{dw_i} = \left[ \frac{dp_i}{dw_i} - 1 \right] NP_i^w + \left[ p_i - w_i - c^1 - \alpha^h t_i^o - 2\Lambda_i^h P_i^w \right] N \frac{dP_i^w}{dw_i} = 0 \quad (11)$$

where

$$\frac{dP_i^w}{dw_i} = \frac{P_i^w(1 - P_i^w)}{[\mu^w + \Lambda_i^w P_i^w(1 - P_i^w)]},$$

$$\frac{dp_i}{dw_i} = \frac{[\mu^d + \Lambda_i^d P_i^d(1 - P_i^d)]}{[\mu^w + \Lambda_i^w P_i^w(1 - P_i^w)]} \text{ and } \Lambda_i^h = \frac{\alpha \alpha^h N \delta}{s_i}.$$

Simplifying (11) and using the market clearing condition (8) leads to

$$\frac{NP_i^w(1 - P_i^w)}{[\mu^w + \Lambda_i^w P_i^w(1 - P_i^w)]} \left[ \frac{(\mu^d + \mu^w)}{1 - P_i^w} - (p_i - w_i - c^1 - \alpha^h t_i^o) + \Lambda_i^h P_i^w + \frac{\delta N \hat{\alpha}^2}{s_i} P_i^w \right] = 0 \quad (12)$$

and hence the candidate Nash equilibrium in prices and wages is given by

$$p_i = \frac{(\mu^d + \mu^w)}{1 - P_i^w} + w_i + c^1 + \alpha^h t_i^o + \Lambda_i^h P_i^w + \frac{\delta N \hat{\alpha}^2}{s_i} P_i^w \quad (13)$$

This wage-price equilibrium cannot be solved analytically, except for the symmetric solution. In addition,  $P_i^w$ , given by Equation (6) and  $P_i^d$  given by relation (7) are now endogenous, which again requires a numerical approach. However, in the duopoly case, the  $n$  equations,  $n$  unknowns (prices and wages) problem, can be simplified. In the case of the duopoly, the expression for  $P_i^w$  reduces to:

$$P_1^w = \left[ 1 + \exp \left( \frac{w_2 - w_1 + \beta_1 - \beta_2 + \alpha^w(t_2 - t_1)}{\mu^w} \right) \right]^{-1}.$$

Moreover, we have from (7) in the duopoly case, we have:

$$P_1^d = \left[ 1 + \exp \left( \frac{p_1 - p_2 + h_2 - h_1 - \alpha^d(t_2 - t_1)}{\mu^d} \right) \right]^{-1},$$

The last two equations imply that there is a linear relation between the price differences and the wage differences. Using equation (13) to compute the price differences, and using the linear relation between the price difference and the wage difference, we get a unique closed form implicit equation in the price difference, which has a unique solution that can easily be found analytically.

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Congestion has the following effects. Firstly, it makes delivery of the intermediate good more expensive. Secondly, there are time costs (schedule delay costs), since the traffic is not able to travel at the free-flow speed ( $t_i^o$ ) even if perfect congestion pricing can be imposed. In addition, if congestion is imperfectly priced, there are queuing costs. These two costs are reflected in the  $\hat{\alpha}^2 \delta NP_i^w / s_i$  term in (13). Further, congestion makes the effective demand function for the subcentres' products steeper as any price decrease will initially attract more customers. However, these customers will themselves increase travel time so that, in the end, the net increase in the number of customers is somewhat lower. The increased price in turn leads to greater profits. A similar argument also applies to wages. If firms reduce prices and increase market share, they will need to attract more workers but the commuting workers will add to congestion.

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## 2.6. Welfare Analysis

In addition to effects on price, profit and market share, we are interested in the welfare implications of the asymmetric model. Welfare per household can be derived from  $W = \max E[U_{ik}]$  since profits are equally distributed among households (Anderson et al 1992). Using the definition of utility (3) and substituting the random variables from (4) and (5) we obtain

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$$U_{ik} = h_k - p_k - \alpha^d t_k + \mu^d \varepsilon_k + w_i - \beta_i - \alpha^w t_i - \mu^w \varepsilon_i + \theta(1 - \beta) + \frac{1}{N} \sum_l \pi_l - T \quad (14)$$

Then, because of the independence of the labour and consumption decisions in (15), we can write

$$W = \Psi + \max_i E[w_i - \beta_i - \alpha^w t_i + \mu^w \varepsilon_i] + \max_k E[h_k - p_k - \alpha^d t_k + \mu^d \varepsilon_k] \quad (15)$$

where  $\Psi = \theta(1 - \beta) + \frac{1}{N} \sum_l \pi_l - T$ . Given that the error terms are double exponentially

distributed, after some further manipulation (see for example Anderson et al 1992), the welfare formulation for the one day economy can be expressed as

$$W = \Psi + \mu^w \ln \left[ \sum_j \exp \left( \frac{(w_j - \beta_j - \alpha^w t_j)}{\mu^w} \right) \right] + \mu^d \ln \left[ \sum_j \exp \left( \frac{(h_j - p_j - \alpha^d t_j)}{\mu^d} \right) \right], \quad (16)$$

which can be further simplified using the market clearing condition, which implies a linear relation between prices differences and wages difference.



This measure of welfare in the short-run uses the equilibrium prices, wages and travel costs calculated by the model, which enter the welfare formulation via the exponential terms and the profit. When we add fully time differentiated congestion pricing in this bottleneck model, half of the sum of schedule delay and queuing costs are converted into toll revenue. This toll revenue corresponds to the direct welfare gain (in terms of saved transport costs) of tolling. There can be indirect welfare gains or losses via changes in profit margins that can change, in the long term, the number of subcentres. Indeed, congestion may lead to over-entry in the longer term, since firms are able to make larger profits in the absence of road pricing (see de Palma and Proost (2005)).

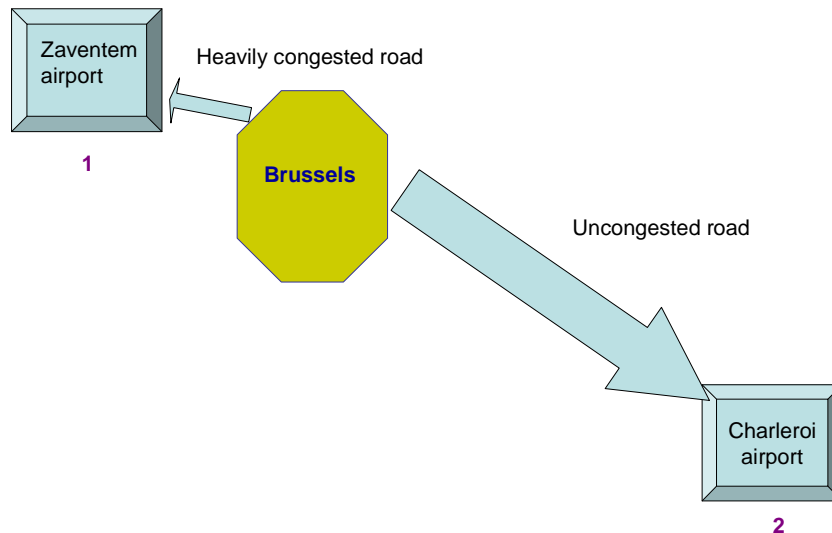
### 3. DUOPOLY EXAMPLE

#### 3.1. *Airport application*

We apply the basic duopoly model to the case of airports offering a package flight and parking facilities as their differentiated product. Increasingly cities in Europe are served by two (or more) airports, which offer differentiated products in terms of quality and frequency of flights but also differ in their facilities and accessibility. Examples include London, which is served by Heathrow, Gatwick, Stansted, Luton and the City airport, Rome (Ciampino and Fiumicino) and Stockholm (Arlanda and Bromma). In this paper we wish to focus on the situation where one airport is located close to the city, offering high quality facilities and frequent flights, while the second is more remote and offers a ‘no-frills’ service. Brussels, Hamburg and Venice can be considered to fall into this category. In particular we concentrate on the case of Brussels International Airport (Zaventem) and Charleroi-Brussels South Airport (Charleroi), which are located 13km and 46km from the centre of Brussels respectively. The model structure is shown in [Figure 3-1](#). We then consider the effect of a number of policy options on prices and wages, market share and degree of transport congestion. Clearly a number of simplifying assumptions need to be made in order to fit the model to this application. However, given this limitation, it is still possible to generate some interesting results from the different policy scenarios.

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**Figure 3-1 Duopoly structure – airport example**

Zaventem airport offers frequent flights to a large number of destinations by a range of airlines. It has good facilities including, for example, 19 cafes and bars. With annual passenger numbers of 15.5 million and car parking for 9000 vehicles, there is some road congestion and queuing for parking. Charleroi, on the other hand is a base for a small number of low cost airlines, flying infrequently to a limited number of destinations. It has limited amenities: only one café. However, with two million passengers per year and parking for over 2000, its road infrastructure is much less congested. We assume in both cases that the bottleneck for road access occurs at the airport entrance. Both airports have public transport connections but we neglect these for the purposes of our comparison.<sup>5</sup>

Both airports offer flights to the same single destination with parking as their differentiated product (henceforth passenger-flight). There are many differentiated destinations offered by the two airports. For the sake of simplicity, we took one common destination, Dublin, to be representative of prices to all destinations. There is no competition between carriers at each airport as, in each case, only one airline offers flights to this destination. Further, our city has a population of 8 million, which is considered to be the approximate number of potential airport customers in Belgium. This city is then assumed to be the only source of passengers and workers at the airports<sup>6</sup>. Clearly this implies that everyone is travelling to the airports along the same route. Although this is not realistic, we can interpret congestion in the model as a bottleneck at the airport entrance, which is where we can expect to experience congestion on the actual road network.

<sup>5</sup> In fact Charleroi has bus connections from each flight to the centre of Brussels and there are at least 3 trains per hour between Zaventem and central Brussels for most of the day.

<sup>6</sup> A gravity model would be a simple method of overcoming this limitation

### 3.2. Model Calibration

We first need to calibrate our model using empirical data for the existing market equilibrium. For ease of exposition, the model described in Section 2.1 has a number of normalising assumptions, which need to be taken into account when using real data. The parameters derived below are presented in terms of the airport economy and have to be scaled appropriately to fit the model.

Weekly passenger numbers are used to determine the proportion of consumers using each airport in equilibrium and the trip frequency ( $\alpha^d$ ). We in fact assume that each city resident consumes one flight per week and adjusts the number of trips he makes accordingly. Data on passenger numbers from the airports tells us that 89% of passengers use Zaventem and 11% Charleroi. We do not allow an outside option.

The uncongested travel times from the centre of Brussels to Zaventem and Charleroi are 16 and 39 minutes respectively. Congestion is assumed to increase travel time to Zaventem by 50% and have no effect on journeys to Charleroi. The bottleneck model is then used to calculate road capacity. Passengers may be considered to have a relatively high value of time (VOT) as there is a high penalty for being late for a flight. Here a value of €20 is adopted<sup>7</sup>.

The frequency of commuting trips ( $\alpha^w$ ) has been approximated using employment figures for the airports. Prices per passenger-flight are calculated from the lowest available advance internet weekend fare to Dublin with roughly the same departure and arrival times. The cost of one day long term parking is then added to this. Airport costs are determined by imposing that the airports break even and charge airlines and parking at cost. These costs are divided into fixed and variable components. The corresponding wages are obtained directly from labour costs, which are assumed to be 35% of total costs. This corresponds to an annual gross salary of approximately €70000. We then allow for the fact that the average wage at Zaventem is likely to be higher given its size, location and quality.

[Table 3-1](#) and [Table 3-2](#) below contain a summary of the fixed and variable data for the airport example.

n	No of airports	2
N	No of consumers	8000000
$\mu^d$	Consumer heterogeneity for airport - passenger	7
$\mu^w$	Consumer heterogeneity for airport employee	5
$\alpha^d$	No of trips per passenger flight	0,04375

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<sup>7</sup> This is in line with business VOT from UNITE (1998).

$\alpha^w$	No of trips per hour of labour	0,13
$\delta$	Scaling parameter for congestion costs	0,25
$\theta$	No of hours per week spent on non-airport employment	37,4
$\beta_0$	Disutility of labour for non-airport employment	0

**Table 3-1 Fixed model inputs**

		Zaventem	Charleroi
Model inputs			
$h$	Airport quality (€/passenger flight)	100	0
$\beta$	Disutility of labour (€/hour)	0	0
$t^0$	Uncongested travel time (hours)	0,53	1,3
$s$	Road capacity (vehicle/week)	356408	10000000
$c$	Variable costs (€/passenger flight)	100	80
$F$	Fixed costs (€/week)	22385720	1541440
Market data			
price ( $p$ )	(€/passenger flight)		
wage ( $w$ )	(€/hour)		
market share	% city inhabitants	89	11

**Table 3-2 Variable model inputs and existing market equilibrium**

Assigning a monetary value to utility of consumption ( $h$ ) and disutility of labour ( $\beta$ ) is not straightforward. Since, passenger-flight prices and congestion costs are higher for consumers using Zaventem in preference to Charleroi, we assume that this difference in cost is compensated for by  $h$ . In addition  $h$  contains a premium for the perceived quality of the product at Zaventem. For  $\beta$ , we simply assume that residents have the same inclination to work at both airports. Finally, we neglect the cost of road infrastructure and any government levies or head taxes. These have no impact on the market equilibrium but affect welfare.

Since we have price, wage and market share information, which are the model outputs, as well as the input data (costs, utilities and transport parameters), we can calibrate the

model to obtain  $\mu^w$  and  $\mu^d$ <sup>8</sup>. In this case  $\mu^w = 5$  and  $\mu^d = 7$  so that the city inhabitants have a stronger preference for the airport they fly from than their work location<sup>9</sup>. The model results for the reference case using these values for  $\mu^w$  and  $\mu^d$  are shown in [Table 3-3](#) below.

airport	price	wage	profit	gross profit	market share	welfare
	€	€/hour	€/inhabitant	€/inhabitant		hours of labour / inhabitant
Zaventem	182,73	45,87	62,05	64,84	88,95	27,019
Charleroi	96,97	37,22	0,80	0,99	11,05	

**Table 3-3 Model results for reference case**

The results indicate that airlines at Zaventem can charge a high price for flights relative to Charleroi because of the high quality (utility of consumption,  $h$ ) of this airport. It is only consumers' relatively strong preference for departure location,  $\mu^d$ , which prevents Zaventem from capturing an even larger market share. Clearly its profits are considerably higher than Charleroi.

### 3.3. Capacity expansion to Zaventem

The first policy scenario we consider is a 50% increase in road capacity to Zaventem. This could also be interpreted as better airport access to parking.

airport	price	wage	profit	gross profit	market share	welfare	$\Delta$ Welfare
	€	€/hour	€/inhabitant	€/inhabitant		hours of labour / inhabitant	% GDP
Zaventem	182,80	45,57	62,20	64,99	88,99	27,203	0,5
Charleroi	96,97	37,22	0,80	0,99	11,01		

**Table 3-4 Model results for capacity extension**

Note that the wage for Charleroi remains unchanged because this is held fixed in the model. Recall that only price minus wage can be calculated for each airport. The changes in prices, profits and market share after the capacity expansion are very small.

<sup>8</sup> This is done by substituting the data from [Table 3-1](#) and [Table 3-2](#) into equations (6), (7) and (13).

Although  $\mu^d + \mu^w$  can be calculated quite easily, the value for each parameter is obtained by trial and error to get a best fit to the data.

<sup>9</sup> These values strongly depend on the other model parameters: for example, if we assume a disutility for working at Charleroi without changing any other parameters, then  $\mu^w = 10$  and  $\mu^d = 7$ , so preferences are reversed.

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The main reason for this is the high value of  $\mu^d$ . Thus the reduction in travel costs only makes Zaventem more attractive to a very small proportion of the potential passengers. The airport can slightly increase its price and reduce the wage it offers because both customers and employees have smaller travel costs but the changes are very small as reducing prices attracts more customers, increasing congestion. Welfare increases compared with the reference case because consumers experience reduced travel costs and Zaventem makes greater profits, which are returned to the consumer in our economy. The welfare gain is however a gross gain as we have not taken account of the cost of building this additional infrastructure. ..

### 3.4. Road pricing

The second policy option is to impose perfect time-differentiated tolling so that some consumers leave home earlier or later and queuing is eliminated..

airport	price	wage	profit	gross profit	market share	welfare	$\Delta$ Welfare
	€	€/hour	€/inhabitant	€/inhabitant		hours of labour / inhabitant	% GDP
Zaventem	182,70	45,88	62,04	64,84	88,98	27,273	0,7
Charleroi	96,97	37,22	0,80	0,99	11,02		

**Table 3-5 Model results for road pricing**

Again, changes in the price-wage equilibrium are very small compared with the reference case; As explained earlier this is due to the particular set-up of the two airport economy and the high value of  $\mu^d$ . Travel costs are also relatively small compared with other costs in the model. These depend on the value of time, which could probably be higher for passengers on their way to the airport.

The route to Charleroi is not tolled as there is no congestion. The average toll for Zaventem reflects the queuing costs and the total toll revenue is a social benefit, increasing welfare. The elimination of queuing attracts more customers to Zaventem but the airport is forced to lower its price and increase its wage to maintain this market share because of the tolls. These changes also represent a benefit to the consumer and welfare is larger than the reference case and when road capacity is increased.

### 3.5. Government subsidy of Charleroi airport

One possible policy that would be attractive to politicians is to subsidise the smaller airport directly so that its marginal costs are reduced. We examine the effect of a 10% subsidy.

airport	price	wage	profit	gross profit	market share	welfare	$\Delta$ Welfare
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	€	€/hour	€/inhabitant	€/inhabitant		hours of labour / inhabitant	% GDP
Zaventem	175,66	45,32	55,08	57,88	87,77	27,204	0,5
Charleroi	89,09	37,22	0,92	1,11	12,23		

**Table 3-6 Model results for marginal cost subsidy**

The marginal cost subsidy allows Charleroi to reduce its price quite significantly and increase its market share. Again, the size of the swing is governed by  $\mu^d$ . Zaventem is forced to reduce its prices to compete and suffers a reduction in profits. Surprisingly, this policy increases social welfare: the benefit to consumers of reduced prices combined with lower congestion to the congested airport outweighs the cost of the subsidy to society and the overall reduction in the airport profits.

### 3.6. Additional airport

It is interesting to consider the effect of an additional small, low-cost airport entering the market. For simplicity we assume the new airport is identical to Charleroi but in a different location.

airport	price	wage	profit	gross profit	market share	welfare	$\Delta$ Welfare
	€	€/hour	€/inhabitant	€/inhabitant		hours of labour / inhabitant	% GDP
Zaventem	178,00	48,69	56,71	59,50	88,07	26,928	-0,2
Charleroi	96,48	37,22	0,31	0,51	5,97		
New	96,48	37,22	0,31	0,51	5,97		

**Table 3-7 Model results for additional airport**

This additional airport has the same properties as Charleroi and so the main effect is to split the Charleroi market into two halves. The main benefits are increased product heterogeneity (which is valued highly here with our high  $\mu^d$  value) and the reduction of congestion to Zaventem. This second effect is in the end very low because the market share of Zaventem decreases by less than 1%. The cost of a new airport is mainly the extra fixed cost. Welfare will in this case decrease because the gain in congestion is too small.

## 4. CONCLUSIONS

In this paper we have presented a general equilibrium asymmetric model of imperfect competition with congestion and explored its functioning to the competition between two airports. The calibration of the model to congested, nearby Zaventem and to the distant Charleroi airport data in Belgium has shown us that there is a high premium

placed on the quality of Zaventem airport and that consumers have strong preferences for where they fly from. We tested infrastructure policies, road pricing policies, subsidies for the distant airport and finally the creation of a new airport. The preliminary results show little change from the reference equilibrium because of these factors. However, the small changes that are observed in prices, profits, market share and welfare are indicative of the potential effects of these policies in a more flexible model setting.

The same proposed framework could not only be used to analyze the impact of a new airport (beside Orly and Paris Charles de Gaulle, a third airport has been under discussion for Paris for more than a decade), but also to study the impact of closing an old airport. A similar study can be carried out for the construction of a new terminal in an existing airport or the expansion of an existing terminal. In this case, the port authority has to decide as well which airline company will use which terminal (such a discussion has taken place in Minneapolis, for example, where Northwest is a key actor, and has some decision power concerning the usage of the old and the new terminal by other competing companies). The quantitative approach used here could explain what the consequences of such policy are and back-up the regulator decisions (the US DOT, in the example mentioned above).



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