Urban distribution centres and competition among logistics providers: a Hotelling approach

Daniele Crotti, *University of Genoa*[1]   Elena Maggi, *University of Insubria*[2]

March, 2017

Abstract

In recent years several European municipalities have paired market-based measures with urban distribution centres (UDC) in order to reduce CO_2 emissions and make more sustainable urban freight flows. However, UDCs may add reloading costs and extra delivery times which have relevant impact on both urban supply chains and the competition among traditional and UDC-based logistics service providers in terms of service quality and freight rates. By using a duopolistic Hotelling framework, we show that market-based measures and subsidies might be substitutes to enhance the demand for UDC-based providers but public funding can be reduced by improving the quality of UDC services. These results can enlarge the scope for investments in UDC value-adding services in order to decrease private crowding-out effects in the long run.

Keywords: Urban Distribution Centre, City logistics, Sustainable Urban Transport Policy, Hotelling Spatial Competition model, Market-Based Measures, Public Subsidy.

JEL Classification: D43, H23, L13, Q58, R41, R48.

Acknowledgements

For helpful comments, the authors thank Edoardo Croci and all the participants at the 18th Scientific Meeting of the Italian Society of Transport and Logistics Economists (SIET), Genoa, 4 - 5 July, 2016.

---

[1] Corresponding author. Department of Economics, via Vivaldi, 5, 16126 Genoa (Italy), email: daniele.crotti@edu.unige.it

[2] Department of Economics, via Monte Generoso, 71, 21100 Varese (Italy), email: elena.maggi@uninsubria.it

1 Introduction

Urban freight transport plays a crucial role in the sustainable development of many EU cities. In the last years, transportation and information advances, along with globalization, have dramatically expanded trades resulting in more dense urban city centres and crowded roads with goods distribution vehicles. Urban transport generates approximately 23% of overall CO2 emissions of which about a quarter is related to urban freight (OECD, 2014; Schoemaker et al., 2006). As about 80% of the EU population lives in urbanized areas, increasing negative effects of goods distribution turn out to be even more problematic into historical cities, especially in Italy, Spain and France (Erdmenger and Frey, 2010; Dablanc, 2007). Even though the volume of goods delivery vehicles is estimated to be 10-20% of passenger traffic, most polluting freight vehicles largely contribute to negative side effects by producing 16 to 50% of the emissions of air pollutants. More, according to the Air quality in Europe – 2016 Report, despite in past fifteen years a persistent decline in the harmful emissions occurred, the amount of CO2 emissions was in 2014 around 40% higher than the official measurements (EEA, 2016). In economic terms, the adverse impact of road traffic in EU cities resulting in air pollution and gas emissions has been estimated to generate a damage roughly amounting to about 100 billion € each year, corresponding to about 1% of the EU's GDP (MDS, 2012; European Commission, 2007).

Beyond environmental issues, heavy and inefficient vehicles used to deliver goods in the urban areas also make city logistics itself further complex. In comparison to cost, timed-based factors and flexibility are central issues within modern delivery processes (EUROSTAT, 2011). With the future running towards urbanization, hence in European cities efficient urban freight distribution should coexist in hopefully less congested and polluted cities. As urban transportation in the EU faces a number of sustainable development challenges, the European Commission has set the objective of reaching free CO2 city logistics in major urban areas by 2030 (Lebeau et al., 2015). With the major aim to tackle the inefficient utilization of urban freight vehicles (i.e., sub-optimal load factor) which contributes significantly to environmental nuisances, structural solutions to be successfully paired with market-based measured (such as congestion and/or pollution charges) occurred, making several policymakers intervene in order to manage the flow of goods more effectively (Maggi, 2007).[3]

In the last twenty years, probably the most interesting and promising structural solution adopted by municipalities to achieve a more efficient utilization of freight vehicles has been the introduction of urban distribution centres (UDCs). These are logistics facilities usually situated in the proximity of a city centre where deliveries from logistics service providers are consolidated and distributed to urban customers (retailers, households) by using eco-friendly vehicles (Crainic et al., 2009; Browne et al., 2005). In principle, Logistics Service Providers (LSPs) with deliveries scheduled for the urban areas may be able to transfer their loads at UDCs and thereby avoid entering the congested sites. In turn, UDCs' operators sort and consolidate loads from a number of LSPs and delivers them with electric and/or hybrid small vehicles to an agreed delivery pattern providing an opportunity to optimize consignment times and runs.

---

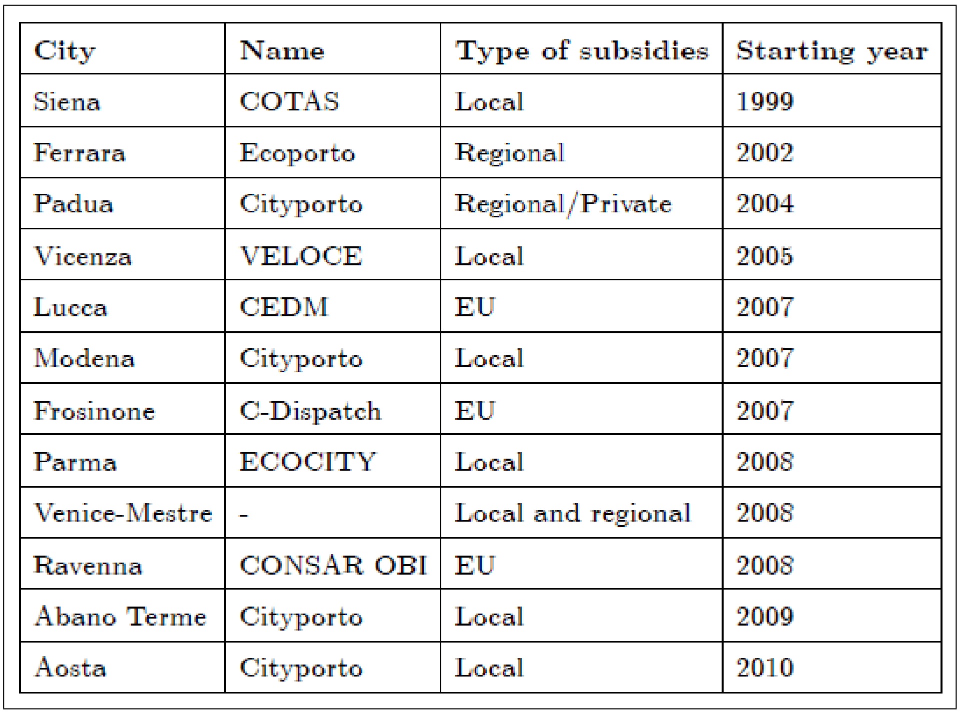
[3] From an integrated freights perspective, Zhang et al. (2015) argue that multiple public policies may have a better network performance as compared with that coming from a single policy type. In other words, incorporating packages of policies could be the best way to optimize freight transports.

Despite the concept of consolidated deliveries dates back to the 1970s (when UK and France started so-called transhipment centres), from the 2000s onward, 25 UDC projects in the UK, 14 in Germany, Italy and the Netherlands, and 11 in France are identified. Several UDC initiates have failed; for instance, in France, the UK and the Netherlands about only 33% of UDCs proceeded beyond a research project or feasibility study, while in Germany and Italy roughly 40% of planned UDCs experienced successful trials and were likely to be fully operational (Allen et al., 2012). Regardless the variable rate of success by country, probably the most crucial issue regarding the introduction of UDCs is the social acceptance of public subsidies often used to sustain their activities.

In times of post-crisis public funding cuts, without a clearly acknowledged acceptance of UDCs by a large number of stakeholders (including taxpayers), there exist obviously concerns about the financial viability of UDCs (Zunder and Ibanez, 2004). The general view is that UDCs must be sustainable by their own in the medium-to-long run as public subsidies are not necessarily a long-term desirable solution. In fact, long-term subsidies might undermine the incentive for UDCs' owners to invest in better equipment and thus they may crowd out quality investments.

As shown in Figure 1, especially in Italy a number of subsidized operational UDCs recently occur (Trentini et al., 2015). At 2014, more than 15 UDCs have been planned having important contributions from public authorities regarding both regulation and funding. The main UDCs in Italy are linked to medium-sized cities (between 100,000 and 500,000 inhabitants) such as Ferrara, Padua, Parma, Siena, and Vicenza, but in the last years, other small cities (e.g., Frosinone and Aosta) have started to develop similar systems. Most Italian UDCs benefit from a large support by public authorities, in the form of direct financing for operational management (Ferrara) or paired restrictive regulations to increase the attractiveness of UDCs (Modena, Parma, and Vicenza). Also in France, the UDC in La Rochelle seems to keep active thanks to public subsidies granted since it was established in 2001. Here, subsidies are provided by the local government for the infrastructure and a fixed amount per package (Ville et al., 2010). In other countries, such as UK or The Netherlands, public funding was absent or low but the number of successful UDCs smaller than those in Italy (Köhler and Groke, 2004).

As a possible remedy, many such funding-dependent UDCs have suggested the need for increasing over-time the proportion of cost recovery from customers and to progressively reduce the level of public subsidies in the long run. In practice, this goal is usually intended to be achieved through signing up new users (i.e., by enlarging own market shares) to generate greater volumes, and/or providing quality improvements (value-adding services) to final customers. For instance, Aastrup et al. (2012) suggest to include in the UDC supply some of the following customers-oriented value-adding services: stockholding, pre-tail activities, order/inventory control, help at delivery, and reverse logistics. Moreover, , e-commerce solutions could be added as they would enable retailers to provide direct benefits to their customers (Dablanc and Rodrigue, 2016). The types of value-added services included in the UDC supply may differ according to the different



City	Name	Type of subsidies	Starting year
Siena	COTAS	Local	1999
Ferrara	Ecoporto	Regional	2002
Padua	Cityporto	Regional/Private	2004
Vicenza	VELOCE	Local	2005
Lucca	CEDM	EU	2007
Modena	Cityporto	Local	2007
Frosinone	C-Dispatch	EU	2007
Parma	ECOCITY	Local	2008
Venice-Mestre	-	Local and regional	2008
Ravenna	CONSAR OBI	EU	2008
Abano Terme	Cityporto	Local	2009
Aosta	Cityporto	Local	2010

Figure 1: Recent UDC experiences in Italy (1999 - onward).

urban supply chain characteristics.[4]

Looking at the empirical cases, the experience of the Cityporto in Padua is widely considered one of the most remarkable Italian successes. After four years of public subsidies (from 2004), it achieved a non-negative balance at the end of the fourth year (2008), when costs were covered by 75% of the total income without subsidies, and this target confirmed from 2009 onward (Morana and Gonzalez-Feliu, 2010). Another example is the UDC in Monaco where LSPs and customers both pay UDC service costs (Patier, 2006). More, van Duin et al. (2010) describe in details the UDC experience in Nijmegen (the Netherlands) where the Binnenstadservice (BSS) received a government subsidy for one year to start-up and then it was able to make money (and cover costs) only by offering value-adding (extra) services such as return logistics dealing with package materials, damaged goods or normal mail.

Despite many cases of successful (directly or not) subsidized UDCs have shown social benefits ranging from reduced congestion and air pollution (including CO2) to improved road safety and parking access, more efforts are required to investigate: a) at what extent transaction costs typically associated to UDCs (extra delivery times due to route diversion and transhipment, UDC service costs) can be offset by a combination of market-based policies (congestion and/or pollution charges) and direct public subsidies and b) how UDC quality investments (for instance, in the form of value-adding services offered in Padua and Nijmegen UDC schemes) may influence LSPs' market shares and freight rates. The present work tries to a give a contribution on these issues, filling a literature gap. In fact, particularly the impact of UDC on the competition among

---

[4] Danielis et al. (2013) define an *urban supply chain* as a part of a supply chain in charge of delivering materials and goods to an urban area.

already existing logistics providers has been devoted a rather scarce attention, but it is a crucial key for the effectiveness of the measure.[5]

To deal with this issue, we develop a duopolistic Hotelling-based framework to study the effects of the introduction of public-private UDCs on LSPs spatial competition. In the model the customers (retailers) are located into city centres and are heterogeneous with respect to delivery times. According to many city logistics experiences in the EU, we consider that the choice of favourite LSPs by retailers is mainly based on freight rates and service quality, and that final delivery services are performed either by traditional or, in alternative, by UDC-based LSPs endowed with relatively less polluting (electric, hybrid) vehicles. In this setting, thus UDCs can be seen as intermediate (downstream) operators which are substitutes for LSPs (by contract) to perform last mile deliveries. Retailers have different preferences for horizontal time-related characteristics of services (according to various supply chains) and also might be influenced by features (such as extra delivery times, market-based measures, public subsidies, and UDC quality investments) when choosing between traditional and UDC-based logistics providers to be patronized. To the best of our knowledge, this is the first theoretical paper attempting to model the impact of UDCs on the quality-price competition among LSPs by contributing to the two strands of literature reviewed below.

The paper is organized as follows. The next section provides an overview on the literature review and explicate the research questions. Then, section 3 presents the model, describing the two scenarios, pre and post-UDC, while section 4 discusses the results, investigating the effects of semi-public UDC on LSPs competition. In particular, we focus our attention on the interplay between public subsidies and UDC quality investments to determine how the latter could trigger decreasing public subsidies and, at the same time, enhanced overall consumer welfare (i.e., on average, higher quality at lower freight rates). In the last section some conclusions and policy implications are drawn.

2 Literature review and research questions

2.1 Literature on urban distribution centres

First, our work contributes to a more conceptual and empirically-based literature related to the analysis of the potential demand for UDC-based services coming from incumbent LSPs. In general, many authors have so far restricted their focus on aspects that on-going (or under trial) UDCs share with others successful experiences (van Duin et al., 2010). The first message is that the potential demand for UDC-based services must be clearly related to the characteristics that, in turn, influence (downstream) requirements shown by retailers and/or shops-keepers.

Usually, the willingness to apply for UDC-based delivery services is high at the start of an initiative (see among others, Ambrosini et al., 2004). A problem in practice, however, is that the number of participating

---

[5] By evaluating twenty-four projects (and focusing on vehicle trips from UDCs to final customers), Allen et al. (2012) identify improvements in load factors ranged from 15% to 100%, reductions in vehicle trips and vehicle kilometres travelled typically between 60% and 80%, and reductions in greenhouse gas emissions from these transport operations ranged from 25% to 80%.

LSPs is usually not stable and lower than expected, which implies less economies of scale and thus less effective bundling possibilities. For example, Regan and Golob (2004) estimate that about 20% of LSPs are willing to use an UDC. For instance, the trial experience of Utrecht has mainly failed because the number of LSPs using the UDC was stood low, thus making the centre not financially sustainable (Cityports Report, 2005). Overall, this literature has identify the following four main factors that are likely to affect the potential demand for UDC-based services.

- Extra delivery times (from UDCs to final customers)

The main problem with the willingness to cooperate in a UDC is that LSPs would not simply give away the delivery of the goods to another party, because of reliability and time-related issues. In a stated-preference study about UDCs' potential demand, for instance, Marcucci and Danielis (2008) show that extra delivery times have a relevant statistical role in explaining the choice between UDCs and alternative traditional means of delivery. As extra delivery times depend largely on how UDCs are well-integrated in the urban context, their location outside the urban areas might have a pivotal importance. It should be clear that this choice largely depends on city characteristics about business activities and population (Crainic et al., 2009). For example, whereas it is suggested that the UDCs should be located in areas with high density of shops (Escuìn et al., 2012), it is also widely recognized that UDCs are unlikely to be attractive for many inner city retailers due to the degree of diversion required from normal routes (Browne et al., 2005). To conclude, the more acceptable solution is that UDCs should, if available, be close to modal nodes (highways, terminals) in order to minimize kilometres driven and reduce the route diversion entailing extra delivery times.

- Different types of urban supply chain involved

Since UDCs enter well-established urban supply chains, much urban freights are already consolidated at intra-company level and it might be very difficult to convince incumbent LSPs to channel their flows of different type of products through a single distribution centre.

In particular, following Danielis et al. (2013), retailers who sell perishable products which require daily-and-fixed consignments (such as fresh fruits and vegetables, milk and dairy products, fish cool, bread and pastry, newspapers, flowers, etc.) are likely to be more time-sensitive – for instance, because they compete with other similar retailers in terms of product selection – with respect to those selling less perishable goods requiring weekly-and-flexible deliveries (e.g., meat, dry food and beverages, frozen food, clothing and footwear, stationary and tobacco, etc.). Hence, more time-sensitive retailers are likely to demand for superior delivery services which UDCs should offer to related LSPs in terms of well-equipped facilities ensuring reliable and high-quality deliveries. However, as happened in Malaga and Barcelona (Spain), single UDCs appear unlikely to be suited for perishable and highly time-sensitive products (Allen et al., 2012).

- Accompanying command and control and market-based measures

Municipalities can indirectly support the UDCs, giving them competitive advantages, by imposing some restrictive measures to non-UDC vehicles. Typically, command and control measures have been directed towards restricting goods delivery vehicles (i.e., time-windows, LTZ, etc.), while market-based measures aim at internalizing the common negative effects of urban deliveries (i.e., through pollution or congestion charges) (Maggi, 2007).

The first type of instruments seem to have further complicate and, in some cases, make more expensive delivery operations. For instance, vehicle time regulations impose specific time-windows within which the goods vehicles can enter (a part of) the urban areas, and the times at which loading and unloading can take place. Examples include the introduction of loading time restrictions in pedestrianized areas served by the UDC (Bristol); the requirement that goods vehicles have at least Euro 3 engines and have a satellite navigation system (Parma); vehicle access restrictions on HGVs (over 3.5 tonnes) between 06:00 and 07:30 in the historic centre (La Rochelle); the total prohibition of goods vehicles over 8.5 tonnes (Monaco); and access restrictions for all goods vehicles in the historic centre (Vicenza). In many cases, however, peak-load hours simply shift from daily to overnight times, making freights more costly for urban retailers (Ville et al., 2010). In other situations, time-windows appeared to have contribute to generate congestion in specific daily-time ranges (Lindholm and Blinge, 2014; Muñuzuri et al., 2005).

Pollution and congestion charges are introduced mainly to price the externalities caused (and commonly disregarded) by road users in city centres where urban delivery operations and traffic congestion are particularly critical. In general, these. As widely observed, pollution charges imply that largely diesel-powered vehicles must pay a fee to enter in a certain area. Differently from congestion charges, pollution charges impose only the payment of fees, without forbidding circulation. Notable examples are in Göteborg, London, Rome, Milan, Oslo, and Stockholm, where charges are proportional to the pollution class of the vehicle. For instance, the Ecopass system implemented in Milan (from 2008 to 2012) entailed an integrated road pricing policy with free daily charges (€0) for low emission vehicles, such as LPG, methane, hybrid and electric geared commercial vans (Croci and Douvan, 2016; Cerruti, 2013).

In terms of measures paired with UDCs, for instance, in Ferrara and Vicenza, the local authorities have put together a number of regulations fostering the use of eco-friendly vehicles for distribution of goods, whereas the experience of the UDC of Paris was bankruptcy since it was not accompanied by supportive measures such as the traffic limitation of heavy and polluting goods vehicles (Cityports Report, 2005).

2.2 Literature on quality-price spatial competition

The second strand of literature on which our work is based concerns the quality-price competition among firms in a standard Hotelling approach. As seen above, many features could combine together to affect the potential demand for UDC-based services. Since the seminal work of Hotelling (1929), a very rich literature has studied the effect of customers' heterogeneity on price competition assuming that consumers incur some "costs" to purchase goods or services from a specific firm. The typical two-fold interpretation of those costs includes either geographical or preference aspects (i.e., the distance between the most-preferred variety and the effective characteristic of goods and/or services purchased). In particular, for a given degree of horizontal differentiation among competitors, the main conclusion drawn from Hotelling-based static models is that market prices would incorporate both production and preference-driven costs incurred by customers. This fact implies that, when the horizontal differentiation is high (or increasing), the price competition is relaxed as firms are able to exert their market power on captive customers, i.e., consumers "located" close to their preferred firm in the spatial framework (see among others, Anderson and De Palma, 1992).

In our paper, following Hu et al. (2014) and Nagurney et al. (2014), we first depart from the traditional literature by assuming that the product 'characteristic' which might differentiate LSPs is represented by delivery times. In terms of industry-specific variables, time-based competition is relevant to services associated with information, such as on-line content distribution, on-line commerce, web hosting (Blackburn, 2012; So, 2000). Likewise, Allon and Federgruen (2007) analyze a general market with service facilities competing on prices and lead time under varying types of competition. In this case, in a setting in which firms make their strategic decisions sequentially by selecting service levels and lead times, the authors show that the competition results in higher service levels, prices, and demand volumes.

Hu et al. (2014) consider how lengthy could be the delivery of products to study the interaction between on-line and off-line distributions in the logistics competition. Whereas off-line competition implies transportation costs (customers have to travel to purchase goods), instead on-line competition entails penalty costs (customers receive goods delivered and thus are sensitive to waiting times). By contrast, Nagurney et al. (2014) develop a game theory model to analyze a supply chain network competition in time-sensitive markets in which consumers respond to the average delivery times associated with various products. In both cases, however, the focus is on the impact of two or more kinds of costs on prices in a Hotelling framework, hence without considering any other variables affecting customers' demand.

Differently from these contributions, we enrich the spatial competition among LSPs by explicitly modelling time-sensitive customers (urban retailers) that are willing to pay a higher price either for more reliable (and faster) delivery times or, in alternative, whenever quality improvements (i.e., implied by value-adding services) may be provided by UDC-based LSPs. In this sense, regarding to the way in which quality is formally introduced in the Hotelling competition, the product differentiation literature has mainly allowed for quality as a strategic variable (not correlated to horizontal differentiation) which is able to enhance customers' willingness to pay for goods and services.

For the purpose of this research, our main reference is Economides (1989) who shows how (relatively cheap) quality investments may give firms the incentive to largely differentiate their products in the variety space (i.e., firms tend to become "insulated" to exert market power). This 'maximal differentiation' suggests that higher quality (together with higher prices as well) have a two-fold effect on demand, that is, (i) local monopolies are more likely to occur and (ii) the full market coverage might be undermined by increasing market prices. In other words, in a spatial competition firms might prefer to "cultivate" their captive customers by competing in quality rather than stealing them each others through a more fierce price competition. By contrast, Ma and Burgess (1993) enrich this result by showing that, however, quality might be also affect the price competition in an opposite direction. Since lower-quality firms have the incentive to reduce prices to maintain own demand, in a competition with strategic complements, average prices might turn out to decline.

In a more general setting, Degryse and Irmen (2001) study firms' incentives to provide quality when it does affect the degree of horizontal differentiation between products. They find that private incentives to provide quality are insufficient relative to the social optimum if a quality improvement reduces horizontal differentiation. Intuitively, here quality improvements reduce the ability of firms to exert market power as quality and preferences are considered as interacting variables. By contrast, in our model these features are assumed to not interact when retailers choose which provider to patronize.

2.3 Research questions

In the light of the above controversial effect of quality on prices and by assuming time-based (horizontal) preferences in the urban logistics competition, our first aim is thus to answer the following question: before the introduction of UDCs, what is the effect of market-based measures (e.g., congestion and/or pollution charges) on the price-quality competition among LSPs? Do they increase freight rates and/or service quality? As we will describe later on, by this study we show that LSPs tend to pass-on market-based measures to urban retailers as (common) costs. Furthermore, whenever retailers are more sensitive to delivery times (i.e., perishable goods, daily-fixed consignments), higher service quality come along with higher freight rates as well. In particular, market-based measures might thus stimulate LSPs to provide higher service quality in order to ensure a fully-covered market (i.e., own-account deliveries are neglected by retailers). But what about their effect on market shares? In a pre-UDC scenario, our model states that demands are not affected neither by preferences for types of deliveries nor by market-based measures. In other words, rather similar incumbents will internalize those features and split market shares proportionally.

In the post-UDC scenario, however, other elements are at play. On the one hand, public subsidies are typically granted in order to make UDC-based services more attractive from the LSPs' perspective (via reducing service costs). On the other hand (and with opposite effects), extra delivery times are likely to harm their potential demand. Thus, the second main aim of our paper is to identify how market-based measures and public subsidies could combine to help UDCs limit their time-based negative externalities. In particular, we would also answer to the following questions. At what extent market-based measures and subsidies granted to UDCs might be substitutes or complements to increase the potential demand for UDC-based LSPs? And what about average freight rates? In this sense, we first will show those policies might be substitutes to increase UDC-based LSPs' demand. As expected, whenever either charges or public subsidies are very high, retailers are more likely to patronize UDC-based LSPs. However, according to Marcucci and Danielis (2008, p. 281), we also theoretically confirm that "[...] businesses with frequent, differentiated, and high-volume deliveries appear less likely to use UDC services [...]". From a social point of view, since highly time-sensitive supply chains are the ones that are likely to generate much urban pollution and congestion, thus extra delivery times and UDC service costs will further weaken the potential demand for UDC-based services.

In terms of post-UDC freight rates, as market-based measures and public subsidies instead are complements in order to lower average freight rates, thus higher charges would call for larger subsidies accordingly. What could be here the role of UDC-based quality improvements? Following the above intuitions drawn from Economides (1989) and Ma and Burgess (1993), our last result will put forward the idea for which enough high quality investments (in the form of value-adding services) might allow local governments to reduce subsidies with the result to convey, on average, higher service quality at lower freight rates in the post-UDC market.

3 The model

In order to include competition issues into the urban logistics market, in our model we extend the standard Hotelling linear-city framework taking into consideration UDC service costs and extra delivery times as main negative externalities suffered from urban retailers patronizing UDC-based LSPs. To evaluate the effects of UDCs on the competition among LSPs, two main scenarios will be contrasted. In the first (pre-UDC) scenario, identical LSPs providing delivery services to urban retailers are assumed to be subject to market-based measures (congestion and/or pollution charges) to enter city centres. In the second (post-UDC) scenario, we will consider the introduction of a public-private distribution centre located away from the city centre (implying a certain level of diversion from normal routes) and assumed to operate by using more eco-friendly commercial vehicles (i.e., free of charges). From the demand side, in our general setting, urban retailers can choose between two LSPs, A and B, each offering one unit of delivery services.

Following Hotelling (1929)'s tradition, we assume that A is exogenously located at 0 on the $X = [0, 1]$ axis, whilst B is located at 1, that is, at the opposite end point of the linear city. A mass of retailers (whose density is normalised to 1) is heterogeneous with respect to LSPs' delivery times, meaning that they are willing to pay a higher price for lower delivery times. In this sense, urban retailers' location between $0 \leq x \leq 1$ is meant here to describe *time-sensitive* retailers who naturally prefer to patronize LSPs that are *closer* in term of time-distance. As a result, in this stylized duopolistic market, whenever both providers offer similar freight rates and service quality, retailers with a low (high) x would patronize LSP A (B) over B (A). Assuming that retailers' preferences are uniformly distributed along the city line, this framework also allows us to capture a key feature of the competition among LSPs, that is, the fact that delivery times might combine with freight rates in order to increase own market shares.[6] Formally, urban retailers enjoy a net

---

[6] As for the elements that drive the choice of third-party LSPs by retailers/customers, Voss et al. (2006) report that delivery reliability is critical to carrier selection, whilst delivery speed and freight rates are also considered to be order winners according to Silveira (2005).

utility of $V_i(x)$ when patronizing one unit of delivery services from LSP $i = (A, B)$, as follows:

$$\begin{array}{ll} V_A(x) = b \cdot q - w \cdot x - f_A & \text{Patronizing A} \\ V_B(x) = b \cdot q - w \cdot (1 - x) - f_B & \text{Patronizing B} \\ (-\infty, 0) & \text{Not patronizing any LSP at all}^7 \end{array} \tag{1}$$

Following Economides (1989), we allow for a utility function that is separable in quality (vertical differentitiation) and variety (horizontal differentiation). In addition to freight rates ($f_A, f_B > 0$), thus retailers' evaluation of a specific third-party LSP is assumed to be affected by two elements, that is, their variable preference for delivery times and LSPs' service quality.[8]

As far as delivery times are concerned, we consider a parameter $w > 0$ that measures the cost of waiting for a unit of time. From the point of view of customers, LSPs are chosen depending on penalty costs deduced by delivery times. In a broader sense, this interpretation allows us to map different urban supply chains, ranging from less time-sensitive retailers requiring weakly-and-flexible consignments (lower w) to more time-sensitive retailers requiring daily-and-fixed consignments (higher w).

In terms of service quality, the choice of a particular LSP by urban retailers is also assumed to be enhanced by the quality of delivery services offered. In this case, we can define the level of service quality as a basic "bundle" of different specific characteristics that improves customers' utility (i.e., relational attributes, full regulatory compliance, etc.). In our setting, LSPs rely upon service quality as a key variable to compete with rivals and, at the same time, to make retailers prefer to patronize third-party providers instead of recurring to own-account deliveries. In the pre-UDC scenario, in order to focus on the effect of freight rates on demand (markets shares), from now on we consider a symmetrical (exogenous) service quality q offered by each LSP. All else equal, this implies that, before an UDC is set up, retailers have the same gross willingness to pay for delivery services. The marginal utility of service quality is measured by the parameter $b > 0$. Summing-up, as described in the above formulation, we formally consider a standard disutility of x (time-distance between LSP A and the retailers' location) times the linear 'costs' of delivery times w incurred by retailers when choosing A as service provider and the related disutility of $(1 - x)$ times w when choosing B.

From the supply side, in the model we assume that both LSPs' operating costs (e.g., delivery logistics, vehicles maintenance, handling) can be accounted for each freight separately and set to zero.[9] However, taking into consideration market-based measures established to reduce traffic nuisances and air pollution,

---

[7] In our formulation, retailers are assumed to not be able to stock up goods as their shops size is constrained. This means that, for very high freight rates set by LSPs, they would consider outside options such as own-account deliveries. For simplicity, we model an utility function for which customers that gain strictly less than zero utility decide to not patronize any LSP at all. In other words, as retailers compete in downstream markets, it is assumed that the competitive quality-based loss they incur being served by LSPs is relatively bigger than the cost of own-account deliveries.

[8] From a transportation perspective, here we apply a generalized cost approach as all the operators along an urban supply chain would contribute to the 'price' of freight delivery. As we will se later on, this view is particularly important when dealing with the post-UDC scenario in which a reloading (downstream) node is added.

[9] Without significant loss of generality, we rule out other transport costs (fuel) and/or fixed costs related to facilities' overheads that are not likely to pass-through to customers in the short run.

in the pre-UDC setting we assume that A and B are traditional LSPs which perform consignments in inner urban areas using own (at some extent) polluting commercial vehicles. As a consequence, these vehicles entail marginal charges $c > 0$ set by municipalities.[10]

3.1 Symmetrical pre-UDC scenario: equilibrium analysis

Before deriving the pre-UDC equilibrium, it is useful to define how LSPs' demand functions are influenced by freight rates and service quality. According to the utility functions described in (1) and given that the share of retailers patronizing A can be identified by its location $0 \leq x \leq 1$, we derive A's demand as:

$$V_A(x) \quad \geq \quad V_B(x) \Longleftrightarrow b \cdot q - w \cdot x - f_A \geq b \cdot q - w \cdot (1-x) - f_B$$

$$\Rightarrow \quad x \leq x(f_A, f_B) = \frac{1}{2} + \frac{f_B - f_A}{2w} \equiv D_A(f_A, f_B) \tag{2}$$

This means that all the retailers indexed by $[0, x(f_A, f_B)]$ will choose LSP A as logistics service provider. As a result, LSP B's (residual) demand is easily derived as:

$$D_B(f_B, f_A) \equiv 1 - D_A(f_A, f_B) = \frac{1}{2} + \frac{f_A - f_B}{2w} \tag{3}$$

and all the customers indexed by $[x(f_A, f_B), 1]$ will patronize LSP B. Retailers located close enough to zero (in terms of time-distance) in the X space are bounded by a threshold value of x above which they prefer to patronize A. In equilibrium, whenever LSPs offer similar levels of service quality and freight rates, the outcome in terms of market share implies the standard Hotelling result for which the market is split into two equal parts, that is, each LSP would gain half the market (as in Figure 3 below). For a given symmetrical service quality offered, thus LSPs must compete in freight rates in order to steal customers from rivals.

To formally derive the equilibrium freight rates, we consider LSPs maximizing the following profit functions with respect to own freight rates:[11]

$$\begin{aligned} \pi_A(f_A, f_B) &= \int_0^{D_A(f_A, f_B)} (f_A - c)\, dx \\ \pi_B(f_B, f_A) &= \int_{D_A(f_A, f_B)}^1 (f_B - c)\, dx \end{aligned} \tag{4}$$

---

[10] From a normative point of view, the parameter c can be also interpreted as a proxy for the share of polluting commercial vehicles existing in an urban area. For instance, higher levels of c would mean that, on average, traditional LSPs make use of diesel-powered vehicles Euro 0, 1, 2, with PM10 emission factors from 50 to more than 100 mg/km.

[11] By assuming delivery costs equal to zero, we focus our attention on the cost-effect of pollution charges and we also rule out (without loss of generality) analytical issues related to the fact that in LSPs' profit functions the standard Hotelling-style transportation costs (horizontal differentiation) are substituted by (time-based) penalty costs for the retailers. In this case, profit functions would have accounted for the physical distance from LSPs' location to each retailer served. See also Hu et al. (2014) for details.

By inserting (2)-(3) in (4) and applying the relative first order conditions, i.e., $\partial\pi_A(f_A, f_B)/\partial f_A = 0$ and $\partial\pi_B(f_B, f_A)/\partial f_B = 0$, we derive LSPs' best response functions as follows:[12]

$$\begin{aligned} f_A(f_B) &= \frac{w + c + f_B}{2} \\ f_B(f_A) &= \frac{w + c + f_A}{2} \end{aligned} \tag{5}$$

Equations in (5) clarify that freight rates are strategic complements between LSPs (i.e., $\partial f_A(f_B)/\partial f_B = \partial f_B(f_A)/\partial f_A = \frac{1}{2} > 0$), as the standard *50 cents-on-the-dollar* property applies. All else equal, indeed an unilateral (marginal) freight rate increase leads to lower overall demand (i.e., the reaction functions shift up only by one-half) but also higher demand for rivals whose marginal revenues shrink, inducing them to raise freight rates as well (taking up the other half of the effect).

By solving the above system and inserting (6) in (2)-(3) respectively, we derive pre-UDC freight rates and market shares in equilibrium as follows:

$$f_A = f_B \equiv f = w + c \tag{6}$$

$$D_A = D_B = \frac{1}{2} \tag{7}$$

From (6), as expected, we notice that LSPs are able to fully pass-on (common) charges to customers. More, for given identical service quality among LSPs in equilibrium, LSP's market power over captive customers (i.e., closer retailers on a time-distance basis) is enhanced by w. In terms of different urban supply chains, this result can be interpreted as follows. The more supply chains are time-sensitive, the larger is the market power that symmetrical LSPs might be able to exert on captive retailers.

The result for which equilibrium demands and prices are not affected by symmetrical service quality is rather standard in Hotelling static models. When quality is assumed identical among LSPs (and/or already set over a minimum standard level), it does not have any impact on market shares and, in turn, on freight rates. Should incumbent LSPs increase symmetrically their service quality (for instance, because they have roughly the same size and/or are endowed with similar IT equipments), own demands are left unchanged because the additional quality offered simply cancels out. In other words, identical quality across firms entails that demand neutrality does channel to price neutrality.

At this point, in order for a fully-covered market equilibrium to exist, we have to make sure that all the customers in the urban city centre would gain a (not strictly) positive utility being served by LSP A or B. In other words, it must be checked whether the "indifferent" customer (located at $x = 1/2$) would gain a utility greater than (or, at least, equal to) zero. This condition holds only if:

---

[12] Second-order conditions for local maxima are fulfilled as $\partial^2\pi_A(f_A, f_B)/\partial f_A^2 = \partial^2\pi_B(f_B, f_A)/\partial f_B^2 = -\frac{1}{w} < 0$.

$$V_A(x = 1/2, f = w + c) = b \cdot q - w/2 - (w + c) \geq 0$$

that is, for a level of service quality (not strictly) greater than a (minimum) threshold denoted by $\overline{q}$:

$$q \geq \frac{1}{b}\left(\frac{3}{2}w + c\right) \equiv \overline{q} \tag{8}$$

Valued at its sufficient level to ensure a fully-covered market (implying that even retailers located nearby the inner city centre would patronize one of the two LSPs), the symmetrical service quality provided in the pre-UDC scenario increases as retailers are more time-sensitive and/or with the extent of market-based measures. Without loss of generality, hence we make the following assumption.

Assumption 1 *In order to ensure a fully-covered market for urban freights (and thus deterring own-account deliveries), LSP A and B supply the minimum level of service quality $\overline{q}$.*

In terms of accompanying measures able to pair the effects of UDCs, Assumption 1 does emphasize how congestion and/or pollution charges set by municipalities affect the level of service quality offered by LSPs. In our setting, the condition under which the urban freights market is fully covered ensures that, in principle, own-account deliveries are essentially ruled out by urban retailers. In particular, when local governments set increasing charges, at the same time, they induce LSPs to provide a level of service quality accordingly. As obverse facet, for a given level of charges, in case of more time-sensitive urban supply chains (higher w), hence Assumption 1 shows that the market coverage is not ensured unless LSPs further increase own (minimum) service quality.

By summing up the results in (6)-(8), finally we state the:

Proposition 1 *(Pre-UDC equilibrium). Before the introduction of UDCs, in a fully-covered market:*

- *freight rates are neutral to symmetrical quality improvements;*
- *market shares are neither affected by market-based measures nor by how retailers are time-sensitive;*
- *the extent of market-based measures (i.e., congestion and/or pollution charges) is channelled to urban retailers in terms of both higher service quality and freight rates.*

A more general interpretation suggested by Proposition 1 is at point here. Before the introduction of UDCs into urban supply chains, market shares are equally spread among symmetrical logistics providers, regardless either the extent of market-based measures (i.e., pollution and/or congestion charges) or the heterogeneity of retailers' elasticity to delivery times. In particular, LSPs are always able to set higher freight rates to more time-sensitive retailers. Intuitively, as in our setting retailers belonging to supply chains with daily-and-fixed consignment requirements (e.g., fresh food, dairy, newspapers, etc.) are willing to pay more for reliable and faster deliveries, LSPs would indeed exert their market power accordingly on captive customers (that is, retailers that are closer in terms of time-distance). In conclusion, with the main aim to help avoiding more polluting and less efficient modes of consignment (e.g., own-account deliveries), market-based measures set by municipalities are passed-through to customers in terms of higher freight rates and have the major welfare-oriented effect of increasing the (minimum) level of service quality provided.

3.2 Asymmetrical post-UDC scenario: equilibrium analysis

In this section our analysis departs from the previous (symmetrical) model of competition among LSPs to allow for the introduction of public-private UDCs in the urban freights market. Although an UDC may be potentially endowed with a monopolistic position in the *last mile* deliveries (i.e., whenever *all the* LSPs in the market perform final consignments making use of a single UDC), here we neglect such a competitive distortion by focusing on unilateral incentives for a given LSP (say, B) to apply for UDC-based services. From a city logistics perspective, adding a downstream stage (reloading or transhipment node) to existing supply chains might influence retailers' choice conducing to an imperfect competition among LSPs in two ways. First, we refer to additional UDC service costs (including also handling, drafting, bargaining, etc.) which might reduce the efficiency of a certain supply chain by distorting (upward) freight rates. Second, whenever retailers are supplied by UDC-based LSPs, they might suffer from a disutility due to extra delivery times measured from UDC consignment to final deliveries. In general, as LSPs taking parcels to an UDC do not deliver goods to the final customers (i.e., retailers' shops), hence it is crucial to investigate what are the conditions (in terms of service costs and quality) under which an LSP is willing to apply for UDC-based services to cover own *last mile* deliveries.

In formal term, the utility function in (1) rewrites as follows:[13]

$$\begin{array}{ll} V_{A^\circ}(x) = b \cdot q - w \cdot x - f_{A^\circ} & \text{Patronizing A} \\ V_{B^\circ}(x) = b \cdot (q + \Delta q) - w \cdot (1 + \alpha - x) - f_{B^\circ} & \text{Patronizing B} \\ (-\infty, 0) & \text{Not patronizing any LSP at all} \end{array} \tag{9}$$

where $\alpha \leq 1/2$ is a parameter that measures how time-consuming features related to UDCs (i.e., transhipment and dwell times, inefficient location) might reduce the utility of retailers which patronize LSP B. This additional *penalty* for customers patronizing LSP B crucially depends on either the distance of UDCs from highways or easy-to-access modal nodes or how well the UDC is integrated into the urban supply chain (i.e., degree of diversion required from normal route). Since UDCs are typically located barely outside city centres to minimize their distance to final customers, here we assume that the related route diversion would imply an additional time-distance between UDCs and retailers (at most) equal to half the size of the city.[14] This choice aims at avoiding unrealistic results for which UDC-based LSPs have zero market shares even by offering similar service quality and freight rates with respect to traditional LSPs. Put differently, we are here

---

[13] With a slight abuse of notation, we label post-UDC figures by using the superscript °.

[14] From an environmental point of view, the optimal location of UDCs shows a trade-off. If UDCs are located several kilometres from the consignment area, then the distance over which more eco-friendly UDC vehicles operate could be maximized. By contrast, if UDCs are located very close to the served area, this choice would reduce the distance covered by eco-friendly vehicles (Browne et al., 2005).

considering that overall freight rates and quality are still more crucial than location and/or route diversion in the market. All else equal, as α increases, the utility loss suffered by LSP B's customers becomes more severe.

As regards the level of service quality offered after the introduction of UDCs, if it is kept identical among providers (as assumed in the previous scenario), therefore UDC-based LSPs would probably set higher freight rates (because of UDC service costs) and thus be less competitive than traditional rivals. In order to allow for quality improvements applied by UDCs, hence we assume that they can provide better (or value-adding) services (indicated by $\Delta q > 0$) with respect to traditional LSPs (still offering service quality $q = \overline{q}$, as in the pre-UDC scenario). In this way, we model a competitive environment in which LSPs would find UDC-based services advantageous only if the "cost" of *last mile* deliveries (in terms of revenue loss) is greater than UDC service costs. Clearly, this might hold unless UDCs are somehow able to provide value-adding services for which retailers are more willing to pay.[15]

Given the above modified utility functions, we derive the LSPs' demand functions as follows:

$$\begin{aligned} V_{A^\circ}(x) \quad &\geq \quad V_{B^\circ}(x) \Longleftrightarrow b \cdot \overline{q} - w \cdot x - f_{A^\circ} \geq b \cdot (\overline{q} + \Delta q) - w \cdot (1 + \alpha - x) - f_{B^\circ} \\ &\Rightarrow \quad x \leq x(f_{A^\circ}, f_{B^\circ}) = \frac{1+\alpha}{2} + \frac{f_{B^\circ} - f_{A^\circ} - b \cdot \Delta q}{2w} \equiv D_{A^\circ}(f_{A^\circ}, f_{B^\circ}) \end{aligned} \tag{10}$$

where $D_{A^\circ}(f_{A^\circ}, f_{B^\circ})$ represents A's demand. Still by focusing our attention on fully-covered markets, B's demand is derived as a residual:

$$D_{B^\circ}(f_{B^\circ}, f_{A^\circ}) \equiv 1 - D_{A^\circ}(f_{A^\circ}, f_{B^\circ}) = \frac{1-\alpha}{2} + \frac{f_{A^\circ} - f_{B^\circ} + b \cdot \Delta q}{2w} \tag{11}$$

Differently from the pre-UDC period, new features may affect LSPs' market shares. In particular, LSP B (A)'s potential demand is positively (negatively) affected by UDC's value-adding services (captured by the parameter Δq). Regarding to the negative impact of α on the demand for UDC-based LSPs, by inspecting (11) we can observe that even by setting identical levels of service quality and freight rates (i.e., $f_{A^\circ} = f_{B^\circ}$ and $\Delta q = 0$), LSP B might be not able to gain the leadership in terms of markets shares because of the above time-consuming aspects related to the UDC. As depicted in Figure 2, for symmetrical quality and freight rates, if extra delivery times turn out to be very large ($\alpha \to 1/2$), generalized costs associated to UDC services will amount to $f_{B^\circ} + w\,(1 - x + \alpha)$ for retailers patronizing LSP B, while they will be still equal to $f_{A^\circ} + wx \equiv f_A + wx$ by choosing LSP A. In this extreme case, LSP A would gain about the 75% of the market (i.e., 3/4) while LSP B the residual 25% (i.e., 1/4). Threfore, UDC-based LSPs cannot dominate traditional

---

[15] Here, our modelisation is strongly inspired to value-adding schemes provided in the City Porto (Padua) or in the Binnenstadservice in Nijmegen (The Netherlands) where UDCs planned to offer many additional services to differentiate themselves from traditional LSPs and gather increasing market shares.

rivals (in terms of market shares) unless by lowering own freight rates ($f_{B^\circ} < f_{A^\circ}$) and/or providing quality improvements ($\Delta q > 0$).

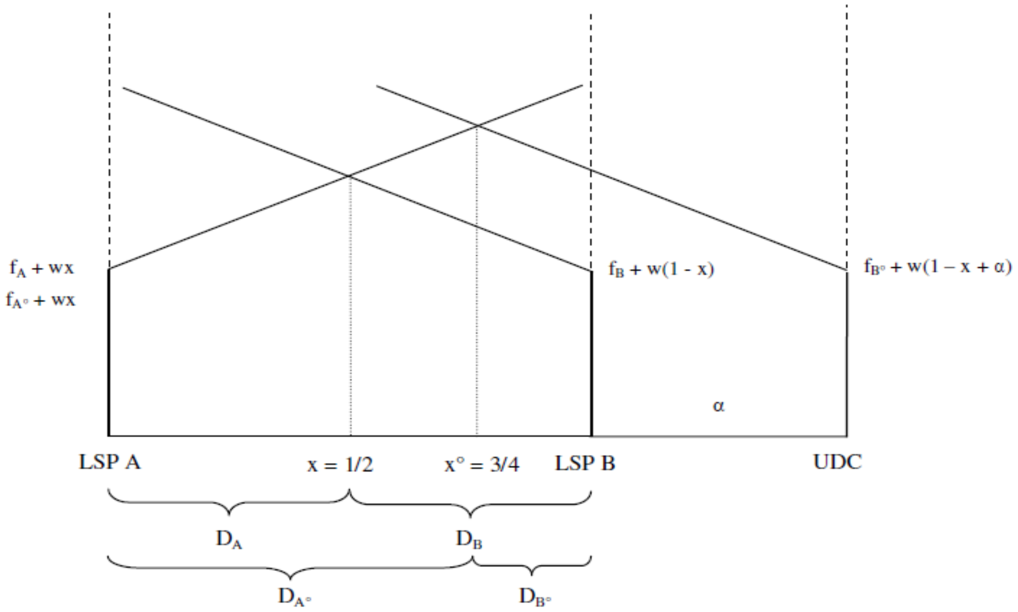


Figure 2: Pre- and post-UDC market shares allocation (symmetrical case).

At this point, in order to derive the post-UDC equilibrium, the timing of the game is extended by considering LSPs competing in two stages:

- In the first stage, a public-private UDC establishes its service costs according to various level of public subsidies granted by municipalities;
- In the second stage, LSP A and B simultaneously set freight rates by taking into account their own demand functions.

After the introduction of UDCs, hence our setting shifts from a symmetrical duopoly to an asymmetrical competition among traditional and UDC-based LSPs in congested and narrow city centres. Therefore, in contrast to charges levied to traditional LSPs who make use of heavy and polluting commercial vehicles (i.e., $c > 0$), we suppose that UDCs perform *last mile* deliveries by using not-polluting vehicles (e.g., electric, hybrid vans). Basically, by applying for UDC-based services, LSP B might be able to avoid charges (i.e., $c = 0$).

In order to find the subgame perfect Nash equilibrium (SPNE) of the game in post-UDC setting, we proceed by backward induction, starting from the second stage where LSPs maximize the following profits with respect to own freight rates:

$$\begin{aligned}\pi_{A^\circ}(f_{A^\circ}, f_{B^\circ}) &= \int_0^{D_{A^\circ}(f_{A^\circ}, f_{B^\circ})} (f_{A^\circ} - c)\, dx \\ \pi_{B^\circ}(f_{B^\circ}, f_{A^\circ}) &= \int_{D_{A^\circ}(f_{A^\circ}, f_{B^\circ})}^{1} (f_{B^\circ} - s)\, dx\end{aligned} \tag{12}$$

where $s > 0$ represents UDC service costs. By substituting (10)-(11) in (12), the first order conditions yield the following best-response functions:[16]

$$\begin{aligned}f_{A^\circ}(f_{B^\circ}) &= \frac{c + (1+\alpha)\, w - b \cdot \Delta q + f_{B^\circ}}{2} \\ f_{B^\circ}(f_{A^\circ}) &= \frac{s + (1-\alpha)\, w + b \cdot \Delta q + f_{A^\circ}}{2}\end{aligned} \tag{13}$$

Still in the post-UDC market, freight rates are strategic complements. Whereas increasing UDC service costs make LSP B's response shift up inducing an increase in own freight rates (i.e., $\partial f_{B^\circ}(f_{A^\circ})/\partial s = 1/2 > 0$), instead UDC quality improvements crucially move LSP A's reaction downward (i.e., $\partial f_{A^\circ}(f_{B^\circ})/\partial \Delta q = -b/2 < 0$). In fact, whenever retailers benefit from value-adding services by patronizing LSP B, in the second stage, the lowest-quality LSP A would reduce its own freight rates to attract demand. Furthermore, increasing values of α contribute to both the reaction functions as LSP B (A)'s reaction would shift down (up).

By solving the above system, we obtain the second stage equilibrium freight rates as functions of both UDC service costs and quality offered:

$$\begin{aligned}f_{A^\circ}(s) &= \frac{(3+\alpha)\, w + 2c + s - b \cdot \Delta q}{3} \\ f_{B^\circ}(s) &= \frac{(3-\alpha)\, w + c + 2s + b \cdot \Delta q}{3}\end{aligned} \tag{14}$$

From (14), both LSPs' equilibrium freight rates increase with charges and UDC service costs (as they represent costs to be passed-on to customers). However, the extent of this effect is different among LSPs. While increasing charges affect A's freight rates more effectively than B's ones (i.e., $\partial f_{A^\circ}(s)/\partial c = 2/3 > 1/3 = \partial f_{B^\circ}(s)/\partial c$), the opposite result occurs dealing with UDC service costs (i.e., $\partial f_{B^\circ}(s)/\partial s = 2/3 > 1/3 = \partial f_{A^\circ}(s)/\partial s$). Here it is important to notice that two-thirds of UDC-based service quality are taken up in terms of increased B's freight rates, while one-third of charges (levied to traditional LSPs only) still impacts on UDC-based LSPs. This means that, although municipalities set market-based measures to deter

---

[16] Second order conditions hold as $\partial^2 \pi_{A^\circ}/\partial f_{A^\circ}^2 = \partial^2 \pi_{B^\circ}/\partial f_{B^\circ}^2 = -\frac{1}{w} < 0$.

traditional (and less eco-friendly) deliveries, in the presence of LSPs' competition in strategic complements, the extent of these charges does contribute to make UDC-based LSPs less competitive (by raising their freight rates).

Going backward we find the sub-game perfect equilibrium of the game by considering, in the first stage, the optimal choice of service costs level made by a public-private UDC. In this case, we consider a distribution facility which maximizes a weighted combination of profits and markets shares to model two key features of several welfare-oriented entities (such as schools, transport companies, hospitals, etc.).[17] First, UDCs may need to make profits in competitive settings with decreasing public resources to spend, that is, facing not-that-soft budget constraints. Second, increasing market shares might be important to public-private UDCs because local governments mainly aim at spreading out more eco-friendly ways to deliver goods in city centres. In other words, whenever UDCs contribute (at some extent) to maximize their vertical-related LSPs' market shares, they also help inner cities to avoid more polluting commercial vehicles. As a consequence, the more UDCs are welfare-oriented (high public subsidies), the more they might be willing to enhance own service quality by (partially) disregarding the related effects on costs.

Formally, we consider an UDC that maximizes the following objective function:

$$W(s) = \int_{D_{A^{\circ}}(f_{A^{\circ}}, f_{B^{\circ}})}^{1} (s + \theta - k \cdot \Delta q)\, dx \tag{15}$$

where $\theta > 0$ is a parameter that measures the direct public subsidies granted to UDC operations. As θ increases, UDCs would take into account general public concerns (such as air quality and traffic congestion) and are willing to set lower service costs to induce more retailers to patronize LSP B.[18] Marginal costs of quality investments are captured by the parameter $0 < k < b$. Two remarks are in order at this point. First, for a given level of quality improvements offered, UDC service costs must be sufficiently low to make LSP B set, in turn, lower freight rates and attract a larger demand. Second, as a welfare-oriented UDC is keen to lower its service costs, this fact potentially leaves smaller market shares (or residual demand) to traditional LSPs. To conclude the analysis of the first-stage equilibrium, we solve the UDC's objective function maximization problem with respect to s (the related first order condition implies $\partial W(s)/\partial s = 0$):[19]

$$s(\theta) = \frac{(3-\alpha)\, w + c - \theta + \Delta q\, (b + k)}{2} \tag{16}$$

The interpretation of (16) reveals that, without a direct public intervention (that is, when $\theta = 0$), the only way for UDCs to lower own service costs is to reduce quality investments as well. Furthermore, in the presence of time-sensitive retailers (high w), the level of UDC service costs increases as well.

Finally, by inserting (16) in (10)-(14), we derive post-UDC freight rates and market shares (demands), respectively. The following formulations:

---

[17] See Herr et al. (2011) for a similar argument.

[18] Obviously, to be economically viable an UDC project must entail enough revenue to cover (often very high) fixed costs. For sake of convenience, however, here we rule out break-even issues (by setting null or already covered overheads).

[19] Second-order conditions are fulfilled as $\partial^2 W(s)/\partial s^2 = -\frac{1}{3w} < 0$.

$$f_{A^\circ}(\theta, \Delta q) = \left(\frac{3}{2} + \frac{\alpha}{6}\right) w + \frac{5c - \theta - \Delta q\,(b-k)}{6} \tag{17}$$

$$f_{B^\circ}(\theta, \Delta q) = \left(2 - \frac{2}{3}\alpha\right) w + \frac{2c - \theta + \Delta q\,(2b+k)}{3} \tag{18}$$

$$D_{A^\circ}(\theta, \Delta q) = \frac{9+\alpha}{12} - \frac{\Delta q\,(b-k) + c + \theta}{12w} \tag{19}$$

$$D_{B^\circ}(\theta, \Delta q) = \frac{3-\alpha}{12} + \frac{\Delta q\,(b-k) + c + \theta}{12w} \tag{20}$$

allow us to state the:

Proposition 2 *(Post-UDC equilibrium freight rates). After the introduction of UDCs, traditional (UDC-based) LSP's freight rates:*

- *increase with either market-based measures or in presence of more time-sensitive retailers;*
- *decrease with public subsidies;*
- *decrease (increase) with UDC quality improvements; and*
- *increase (decrease) with extra delivery times.*

As a result, in order to let UDC-based LSPs be more competitive, market-based measures and public subsidies must be complements.

As far as freight rates are concerned, Proposition 2 first shows that, similarly to the pre-UDC scenario, both retailers' elasticity to delivery times (captured by w) and market-based measures (measured by c) contribute to increase overall freight rates. In other words, after the introduction of UDCs, the above features still allow LSPs to exploit their market power over respective customers. However, in contrast to what concluded in Proposition 1, other aspects associated to UDCs might affect equilibrium freight rates. Firstly, public subsidies will have a downward impact on both LSPs' freight rates, albeit with different magnitudes. Since freight rates are strategic complements, increasing public subsidies lower B's freight rates and channel this effect (at a smaller extent) to A's ones.[20] For the purpose of our research, by Proposition 2 we can conclude that, should UDC-based LSPs set the lowest freight rates, then higher congestion and/or pollution charges have to be paired with large public subsidies as well. Secondly, the ability of UDCs to increase revenues by improving their service quality (e.g., value-adding services which would be channelled to LSP B's freight rates) might be crucially offset by extra delivery times generated by transhipment and route diversion. The reason behind this result is briefly explained as follows. Whereas quality improvements

---

[20] Formally, it is straightforward to check that $|\partial f_{B^\circ}(\theta, \Delta q)/\partial\theta| = 1/3 > 1/6 = |\partial f_{A^\circ}(\theta, \Delta q)/\partial\theta|$.

offered by UDCs have a positive impact on customers' willingness to pay, instead extra delivery times act in the opposite way. Put differently, the highest-quality LSP B has the incentive to raise own freight rates accordingly but, at the same time, it must reduce them in order to cope with a potentially decreasing demand due to extra delivery times.

Turning to equilibrium markets shares occuring after the implementation of UDCs, their determinants are shown in the following:

Proposition 3 *(Post-UDC equilibrium market shares). After the introduction of UDCs, traditional (UDC-based) LSP's market shares:*

- *increase (decrease) in presence of more time-sensitive retailers and extra delivery times;*
- *decrease (increase) with market-based measures, public subsidies, and UDC quality improvements.*

In order to make UDC-based LSPs gain the largest market shares, market-based measures and public subsidies must be substitutes.

Differently from what concluded in the previous section, Proposition 3 shows that, in the post-UDC scenario, equilibrium market shares are strongly affected by features related to public policies. From UDC-based LSPs' point of view, in particular we suggest that their market shares might be enhanced by three elements, i.e., UDC quality improvements, market-based measures, and public subsidies.

In the first case, ceteris paribus, quality improvements make retailers prefer to patronize LSPs which apply for UDC-based services. This implies that, by providing value-adding services, vertically-related LSPs might be able to cope with additional UDC service costs (double marginalization) and extra delivery times (captured by α). However, for given value-adding services, LSP A's captive customers may not switch to another logistics provider unless UDC is able to dramatically reduce extra delivery times (for instance, by limiting the diversion from normal routes and/or arranging UDC not far from highways or modal nodes).

As regards the interplay between market-based measures and public subsidies, Proposition 3 does stress their substitutability in order to let LSP B gain the leadership in terms of market shares. In particular, as done by market-based measures, also increasing public subsidies raise LSP B's market shares and reduce LSP A's ones.[21] To conclude, in order to spread out less polluting deliveries in urban contexts (via larger UDC-based LSPs' demand), more strict market-based measures (e.g., higher charges) would call for reducing public subsidies. At this point, to derive the condition for a fully-covered market to be fulfilled, we must have that:[22]

$$V_{A^\circ}\left(x = D_{A^\circ}(\theta, \Delta q), q = \overline{q}\right) \geq 0 \Longrightarrow b \cdot \overline{q} - w \cdot D_{A^\circ}(\theta, \Delta q) - f_{A^\circ}(\theta, \Delta q) \geq 0$$

By substituting (8), (17) and (19) in the above inequality, in the post-UDC scenario all the retailers decide to patronize at least one of the two LSPs only if:

---

[21] By looking at (19)-(20), we can easily check that $\partial D_{B^\circ}(\theta, \Delta q)/\partial \theta = \frac{1}{12w} > 0$ and $\partial D_{A^\circ}(\theta, \Delta q)/\partial \theta = -\frac{1}{12w} > 0$.

[22] Also in this scenario, the level of service quality offered by not UDC-based LSP is assumed to be equal to the pre-UDC (minimum) level (i.e., $q = \overline{q}$).

$$\theta \geq (3+\alpha)\,w - c - \Delta q\,(b-k) \equiv \theta^{\circ} \tag{21}$$

that is, for a sufficiently high level of public subsidies.

An important result coming from (21) is at point. For whatever level of public subsidies beyond θ°, two outcomes occur, that is, (i) the post-UDC market will be fully covered and, at the same time, (ii) UDC-based LSPs would gain the leadership in terms of market shares. The intuition behind this conclusion is explained as follows. By setting public subsidies at their (at least) minimum level to ensure a full post-UDC market coverage (i.e., $\theta \geq \theta^{\circ}$), we have again avoided some retailers not choosing any LSP and thus we have ruled out the preference for own-account deliveries. In turn, no empty sets of LSPs'customers in the post-UDC scenario also imply that freight rates (dragged downward by public subsidies equal to θ°) are enough low to attract customers located in the middle of the city centre (that is, at $x = 1/2$). As a result, any (even slight) increase in terms of public subsidies would contribute to larger LSP B's market shares.[23]

4 UDC quality investments and public subsidies: a trade-off

In this last section we restrict our attention on the interplay between public subsidies and UDC quality improvements. More precisely, the role of value-adding services (i.e., pre-retail, stocking, tracing and tracking, return logistics, etc.) that could be provided by UDCs is analyzed to understand at what extent this feature (combined to public subsidies) might influence the competition among LSPs in terms of freight rates. Since in our modelisation any quality improvements boost the willingness to pay of customers, indeed they are likely to enhance market power (and thus freight rates). As a consequence, in general, quality improvements offered by UDCs would entail that LSP B's freight rates will be greater than LSP A's ones. Anyway, recalling what concluded in the previous section, in a post-UDC fully-covered market, higher freight rates charged by UDC-based LSPs do not impede to gain larger market shares. In particular, whenever public subsidies are set above their minimum level to ensure the market coverage (i.e., θ must be slightly greater than θ°), UDC-based LSPs are able to gather the largest demand. From a normative perspective, this would entail the following consequence. In principle, the potential welfare-enhancing effect of UDC quality improvements might be unfortunately offset by higher (average) freight rates. In fact, whereas some retailers will enjoy higher quality (via value-adding services) at higher freight rates by patronizing UDC-based LSPs, instead those still choosing traditional (not UDC-based) LSPs would pay less for having a lower quality. Although

---

[23] Formally, by comparing (20) to (19), we can derive the conditions for which UDC-based LSPs are able to grab more market shares (larger demand) with respect to traditional rivals in the post-UDC scenario. This holds when (arguments omitted):

$$D_{B^{\circ}} - D_{A^{\circ}} \equiv \frac{1}{6w}\left(c + \theta + q\Delta\,(b-k)\right) - \frac{1}{6}\alpha - \frac{1}{2} \geq 0$$

only for:

$$\theta \geq (3+\alpha)\,w - c - \Delta q\,(b-k) \equiv \theta^{d} = \theta^{\circ}$$

this result is not necessarily detrimental, it may be worthing to identify the extent at which public subsidies are required to mitigate this alleged price-increasing effect of UDC quality investments. As obverse facet, in case of local governments aiming at gradually reducing the dependence of UDCs from subsidies (for budget reasons and/or to avoid crowding-out effects in the long run), thus we would like to investigate whether relatively high UDC quality improvements and decreasing public subsidies can be compatible with a post-UDC scenario in which, on average, retailers will enjoy a higher service quality at lower freight rates.

Before tackling this issue by considering post-UDC average freight rates, we must first derive the level of public subsidies for which LSP B's freight rates are likely to be lower than LSP A's ones. By comparing (17) and (18), we observe that, after the introduction of UDCs, LSP B may be (not strictly) more competitive than A when (arguments omitted):

$$f_{A^{\circ}} - f_{B^{\circ}} \equiv \frac{\theta + c - (3 - 5\alpha)\, w - \Delta q\, (5b + k)}{6} \geq 0$$

for:

$$\theta \geq (3 - 5\alpha)\, w - c + \Delta q\, (5b + k) \equiv \theta^{f} \tag{22}$$

At this point, we may wonder whether any positive level of quality investments would increase UDC-based LSPs' freight rates, thus calling for larger public subsidies. Intuitively, since in our modelisation value-adding services increase the willingness to pay of UDC-based LSPs' customers, then quality features might enhance market power (and thus freight rates). As a consequence, in general, quality improvements would entail that LSP B's freight rates are expected to exceed LSP A's ones.

In this sense, by looking at (21) and (22), we find that the threshold θ^{f} is (not strictly) greater than θ° when:

$$(3 - 5\alpha)\, w - c + \Delta q\, (5b + k) \leq (3 + \alpha)\, w - c - \Delta q\, (b - k)$$

that is, only for a relatively high level of value-adding services, i.e., $\Delta q \geq \alpha w / b$. In other words, whenever UDCs offer sufficiently high quality improvements (with respect to the retailers' elasticity to delivery times, measured by w), for $\theta^{f} \geq \theta \geq \theta^{\circ}$, UDC-based LSPs are leaders in terms of market shares but their customers will likely be destined to pay more with respect to traditional LSPs' ones. In this case UDC quality improvements are completely channelled to LSP B's freight rates (i.e., $f_{B^{\circ}} \geq f_{A^{\circ}}$). By contrast, any level of public subsidies larger than θ^{f} would let UDC-based LSPs gain the largest market shares at the lowest freight rates (i.e., $f_{B^{\circ}} < f_{A^{\circ}}$). In other words, in a fully-covered post-UDC market, the relative extent of UDC quality improvements does combine with public subsidies to determine whether UDC-based LSPs would be able to strive own market power over customers. The stronger the public effort in terms of subsidies, the higher is the ability of UDC-based LSPs to profitably operate in the market (i.e., larger revenues coming from value-adding services). In turn, this would imply that very high subsidies would also positively affect the potential demand for UDC services by LSPs.

At this point, in order to compare pre- and post-UDC average freight rates, we first define the latter as:

$$\overline{f} \equiv \frac{f_{A^\circ} + f_{B^\circ}}{2} \tag{23}$$

then, by making use of (6) and (23), we have that:[24]

$$f - \overline{f} = \frac{\theta + c - (3 - \alpha)\, w - \Delta q\, (b + k)}{4} \geq 0$$

only if:

$$\theta \geq (3 - \alpha)\, w - c + \Delta q\, (b + k) \equiv \theta^{\overline{f}} \tag{24}$$

In order to check whether, for $\Delta q \geq \alpha w/b$, $\theta^{\overline{f}}$ is effective in a fully-covered post-UDC market (i.e., $\theta^{\overline{f}} \geq \theta^\circ$), we compare (21) and (24). In particular, since:

$$(3 - \alpha)\, w - c + \Delta q\, (b + k) \geq (3 + \alpha)\, w - c - \Delta q\, (b - k)$$

always holds for relatively high quality investments, we can conclude that both the thresholds θ^f and $\theta^{\overline{f}}$ are greater than θ° for $\Delta q \geq \alpha w/b$. Turning to the comparison between θ^f and $\theta^{\overline{f}}$, by using (22) and (24), we also have that:

$$(3 - 5\alpha)\, w - c + \Delta q\, (5b + k) \geq (3 - \alpha)\, w - c + \Delta q\, (b + k)$$

again for $\Delta q \geq \alpha w/b$. This means that, in the considered region of Δq, θ^f is (not strictly) greater than $\theta^{\overline{f}}$ as well. Summing up, for $\Delta q \geq \alpha w/b$, the ranking of thresholds related to public subsidies (in descending order) is the following: $\theta^f \geq \theta^{\overline{f}}$ $(\geq \theta^\circ)$.

In summary, we can state the following:

Proposition 4 *(Trade-off between public subsidies and UDC quality investments). In a fully-covered post-UDC market:*

- *for relatively high UDC quality investments (with respect to retailers' elasticity to delivery times), decreasing public subsidies might be compatible with welfare-enhancing average freight rates in the market;*
- *the above required level of quality investments (i.e., value-adding services) is positively affected by both the type of retailers' supply chain (more or less time-sensitive) and the extent of extra delivery times associated with UDCs' operations.*

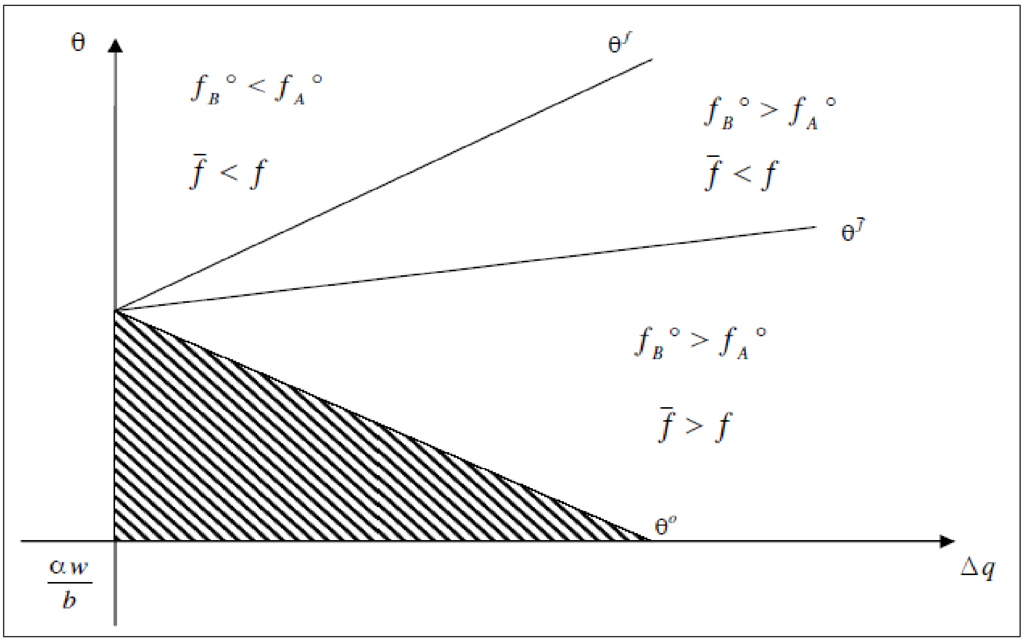


Figure 3: Trade-off between public subsidies and UDC quality investments.

As also described in Figure 3, Proposition 4 clarifies two main results related to the competitive interplay between UDC quality investments and public subsidies in the post-UDC scenario.

Firstly, in presence of sufficiently high UDC quality improvements (proportional to how retailers' supply chains are time-sensitive), we can enlist three relevant levels of public subsidies affecting LSPs' competition in freight rates.

For relatively very high subsidies (i.e., $\theta > \theta^f \geq \theta^{\overline{f}} \geq \theta^\circ$), as expected, UDC-based LSPs can gain the largest available portion of market shares at the lowest freight rates. In practice, they are able to gain an almost monopolistic position (i.e., D_{B° tends to the total demand) by lowering dramatically own freght rates (i.e., $f_{B^\circ} < f_{A^\circ}$). In a sense, they cannot exert a significant market power over captive customers and, as a result, average freight rates will shrink. From a consumer welfare perspective, this is probably the best outcome: higher service quality for almost the entire population of customers (retailers) in the market paired with decreasing equilibrium freight rates. However, this might also imply very high costs in terms of public budgeting. In this case, local governments granting subsidies to sustain UDCs might not indeed commit to gradually reduce crowding-out effects (i.e., private investments are not incentivized) and/or to diminish the dependence of UDCs upon public resources (with negative consequences on their social acceptance).

By contrast, for relatively very low subsidies (i.e., $\theta^f \geq \theta^{\overline{f}} > \theta \geq \theta^\circ$), UDC-based LSPs are still able to dominate the market even though at a smaller extent (i.e., D_{B° would be slightly larger that D_{A°). In addition, they will set higher freight rates with respect to traditional LSPs (that is, by imposing a larger market power), inducing post-UDC average freight rates to rise up (i.e., $f_{B^\circ} > f_{A^\circ}$ and $\overline{f} > f$). In a sense,

---

[24] In our model, by considering not demand-weighted average freight rates, we would focus on the extent of post-UDC competition in freight rates.

this situation might allow local governments to reduce the alleged dependence of UDCs upon public subsidies, but at a very high cost in terms of consumer welfare. In fact, less urban retailers would benefit from higher UDC-based service quality and also, on average, consumers will be worse off (as post-UDC freight rates are higher).

However, as shown in Figure 3, there exists an intermediate region of public subsidies for which both private and public objectives might be satisfied. In particular, for a level of subsidies between $\theta^{\overline{f}}$ and θ^{f}, the following scenario would occur: (i) UDC-based LSPs can grab a significant portion of the market (i.e., D_{B° would be effectively larger that D_{A°) and also exert some market power over customers (i.e., $f_{B^\circ} > f_{A^\circ}$); (ii) on average, consumers are better off as post-UDC equilibrium freight rates are lower than pre-UDC ones (i.e., $\overline{f} < f$); and (iii) local governments may be able to increase the social acceptance of UDCs as subsidies are not that high and also a rather large set of retailers can benefit from a higher service quality (by patronizing UDC-based LSPs). The intuition behind this last result can be briefly explained as follows. By recalling Proposition 2, whenever UDC quality investments are relatively high (increasing Δq), LSP B's freight rates could expand while LSP A's ones shrink, making the former exert market power (at some extent) over own captive customers. However, as the impact of public subsidies on B's freight rates is more effective than A's ones, thus the minimum required level of θ in order to reduce average freight rates turns out to be lower. As a result, despite UDC-based LSPs are less competitive than traditional rivals, overall customers are better off (i.e., a relatively larger number of retailers would benefit from higher quality at lower freight rates).

Secondly, the impact of the heterogeneity of urban supply chains (i.e., how retailers are time-sensitive in terms of delivery times) may be crucial in order to determine the extent of welfare-enhancing UDC quality investments. In fact, Δq has to be higher than an increasing function of w and α, respectively. All else being equal, hence the second result in Proposition 4 does stress out the fact that more time-sensitive retailers - along the discussion we have referred to supply chains in which daily-and-fixed consignments would be required, as in the case of perishable goods like fresh food, newspapers, flowers, milk and dairy, etc. - would need higher UDC quality investments accordingly to boost vertically-related LSPs' demand (and market shares). In an analogous way, structural conditions affecting the extent of extra delivery times (e.g., UDC location and route diversion) are likely to influence (upward) the required level of UDC quality investments.

5 Concluding remarks and policy implications

In this paper we use a spatial competition framework to study the effects of the introduction of UDCs on the competition among third-party logistics service providers. Our analysis has been conducted under two different scenarios. In the first (pre-UDC) scenario, as widely observed in many crowded and polluted cities around Europe, traditional LSPs perform parcels consignments to urban retailers into inner city centres (the so-called last mile) by competing in service quality and freight rates but also facing market-based measures (i.e., congestion and/or pollution charges) set by municipalities to help reducing air pollution and traffic congestion (e.g., in London, Stockholm, Milan, Paris, etc.). In the second (post-UDC) scenario, public-private UDCs are introduced into already established urban supply chains. In fact, by applying for UDC-based delivery services, vertically-related LSPs admit costs and benefits. On the one hand, extra delivery times (due to the fact that, for instance, UDCs may not be well-located outside urban areas and/or transhipments operations cause dwell times) and UDC service costs combine together to cause more expensive supply chains. On the other hand, however, free-of-charge deliveries (very often, UDCs make use of eco-friendly electric commercial vehicles) and publicly subsidized UDC service costs may be able to reduce freight rates. In addition, as exhibited in recent successful experiences of UDCs in the EU - notably, we refer to either the City Porto in Padua (Italy) or the Binnenstadservice in Nijmegen (the Netherlands) - UDCs might invest in service quality improvements (in the form of value-adding services such as pre-retail, stocking, tracing and tracking, return logistics, etc.) to reach a two-fold goal, that is, to increase their potential demand (coming from incumbent LSPs) and thus to be financially viable without relying upon subsidies in the long run.

By taking into consideration urban retailers that belong to variable time-sensitive supply chains, in this work we investigate the theoretical conditions under which LSPs might profitably apply for UDCs (i.e., to gather larger market shares) in a market in which service quality and freight rates are the main determinants of customers' choice. In this way, we obtain two main results.

First, by assuming that in the fully-covered pre-UDC setting service quality is symmetrical among LSPs (for instance, in case of incumbent integrators such as UPS, TNT or DHL having similar technology and/or company size), we first show that either the extent at which retailers are time-sensitive or the level of market-based measures set by municipalities might have the major effect to make traditional LSPs increase the (minimum) service quality offered. As a result, while market shares are not affected by service quality in the symmetrical pre-UDC scenario, instead retailers' preferences for delivery times and market-based measures are passed-on to related customers. In particular, in the pre-UDC scenario, these features may allow LSPs to exert market power over exclusive urban retailers accordingly. For instance, in the presence of retailers belonging to more time-sensitive supply chains (e.g., bread and pastry, newspapers, fish cool, etc.), LSPs might charge higher freight rates as their time-distance to captive retailers is smaller. Therefore, before the introduction of UDCs in the competition among LSPs, we can conclude that, for whatever type of retailers' supply chain (characterized by daily-and-fixed or weekly-and-flexible consignments), market-based measures might effectively contribute to increase service quality to avoid more polluting forms of deliveries, i.e., own-account deliveries. Hence, this normative tool seems to be particularly suitable (and thus to be encouraged) in several historical cities (especially in Italy) where more polluting and less efficient deliveries are largely spread out.

Second, after the introduction of public-private UDCs in urban supply chains, however, market-based measures might have a more subtle effect on the price-quality competition among logistics providers. On the one hand, they increase freight rates associated to traditional third-party consignments and thus give urban retailers the incentive to patronize UDC-based logistics service providers. In a sense, as widely recognized, public intervention by municipalities in the form of public subsidies paired with sufficiently restrictive market-based measures might be decisive to stimulate eco-friendly urban freights. On the other hand, however, since logistics service providers compete in strategic complements (freight rates), those measures may contribute to make UDC-based logistics companies more expensive as well. Furthermore, if we take into account additional "costs" associated to UDCs, such as the double marginalization problem (i.e., downstream freight rates have to incorporate UDC service costs) and extra delivery times (e.g., UDCs are often not well-located outside urban areas), market-based measures imply two main controversial consequences.

In the first case, as congestion and/or pollution charges increase, the potential demand for UDC-based services might effectively be raised even in the presence of lower public subsidies. In particular, as charges negatively affect the demand of traditional LSPs, thus market-based measures and public subsidies might be considered as complements in order to boost the potential demand for UDC-based LSPs' deliveries. In this case, we can refer to the V.E.L.O.C.E. distribution centre established in Vicenza (Italy) in 2005 where several municipal ordinances were applied (from April 2005 to December 2006), progressively reducing the traffic access to the local LTZ. Pairing these measures with a local UDC, the municipality was allowed to sustain the UDC's demand and thus facilitating its financial stand-alone viability.

In the second case, however, as market-based measures contribute to overall higher freight rates, they must be considered as substitutes to public subsidies in order to enhance the consumer welfare in terms of average post-UDC freight rates. At this point, by assuming that public-private UDCs may be able to make investments to improve own service quality (i.e., value-adding services), we obtained the last important result of our model. Whenever quality investments are enough large to cope with either more time-sensitive retailers' supply chains or extra delivery times induced by consolidation and/or route diversion, we show that a larger part of urban retailers would benefit from higher quality services (through UDCs) at lower average freight rates. From a public welfare point of view, hence quality improvements may substitute for public subsidies in order to reduce overall freight rates. In a sense, whenever UDCs invest in quality improvements, decreasing public subsidies can be sustainable in the long run and also UDCs might be viable as well. This last result seems to confirm recent experiences of successful UDCs where several value-adding services are provided and public subsidies have been gradually reduced, such as the CityPorto in Padua (Italy) or the Binnenstadservice in Nijmegen (the Netherlands). In particular, after 2009 (that is, the agreed expiration year for subsidies), in the Cityporto in Padua tailored and specific know-how was developed to answer logistics needs by proposing a wide variety of value-adding services including storage, management services, and assistance to national/international transports, focusing on rail-road intermodality.

Since the obtained results are encouraging, the future next step of the research will aim to empirically validate the model, by collecting data from at least two case studies of successful UDC implementation and building up structured interviews with LSPs, retailers, municipal delegates and other stakeholders involved in the projects. Thus, we will able to describe in details which are the business models applied the UDCs and their evolution in the last years of activity, as a reaction to public subsidies progressively decrease over the time.

6 References

Aastrup, J., Gammelgaard, B. and G. Prockl (2012), *3PL Services in City Logistics*, Proceedings of the 24th Annual Nordic Logistics Research Network Conference (NOFOMA), Oulu, Finland.

Allen, J., Browne, M., Woodburn, A., and J. Leonardi (2012), *The role of urban consolidation centres in sustainable freight transport*, Transport Reviews, vol. 32(4), pp. 473-490.

Allon, G., and A. Federgruen (2007), *Competition in service industries*, Operations Research, vol. 55(1), pp. 37-55.

Ambrosini, C., Routhier, J. L., and F. Toilier (2004), *How do urban policies work on urban goods transport flows*, WCTR, Istanbul.

Anderson, S.P., and A. De Palma (1992), *The Logit as a Model of Product Differentiation*, Oxford Economic Papers, vol. 44(1), pp. 51-67.

Blackburn, J.D. (2012), *Valuing time in supply chains: Establishing limits of time-based competition*, Journal of Operations Management, vol. 30, pp. 396-405.

Browne M., Sweet M., Woodburn A., and J. Allen (2005), *Urban freight consolidation centres final report*, Transport Studies Group, University of Westminster, 10.

Cerruti, D. (2013), *No free polluting anymore: The impact of a vehicle pollution charge on air quality*, 2013 Annual Meeting, August 4-6, 2013, Washington, D.C. 150575, Agricultural and Applied Economics Association.

Crainic, T.G., Ricciardi, N., and G. Storchi (2009), *Models for evaluating and planning city logistic transportation systems*, Transportation Science, vol. 43(4), pp. 432-454.

Croci, E., and A. Douvan (2016), *Urban Road Pricing: A Comparative Study on the Experiences of London, Stockholm and Milan*, IEFE WP 85, Università Bocconi, Milan.

Dablanc, L. (2007), *Goods transport in large European cities: Difficult to organize, difficult to modernize*, Transportation Research Part A: Policy and Practice, vol. 41(3), pp. 280-285.

Dablanc, L., and J.P. Rodrigue (2016), *The Geography of Urban Freight*, In: G. Giuliano and S. Hanson, The Geography of Urban Transportation, 4th Edition, New York: The Guilfold Press.

Danielis, R., Maggi, E., Rotaris, L., and E. Valeri (2013), *Urban Freight Distribution: Urban Supply Chains and Transportation Policies*, in: Freight Transport Modeling, Emerald Group Publishing (editors: Ben-Akiva M., Meersman H., Van De Voorde E.)

Degryse, H., and A. Irmen (2001), *Attribute dependence and the provision of quality*, Regional Science and Urban Economics, vol. 31(5), pp. 547-569.

Duin, J.H.R. van, Quak, H., and J. Muñuzuri (2010), *New challenges for urban consolidation centres: A case study in The Hague*, Procedia-Social and Behavioral Sciences, vol. 2(3), pp. 6177-6188.

Economides, N. (1989), *Quality variations in the circular model of variety-differentiated products*, Regional Science and Urban Economics, vol. 19(1), pp. 235-257.

EEA (European Environment Agency), *Air quality in Europe – 2016 Report*, No 09/2013, available at: www.eea.europa.eu.

Erdmenger, C., and K. Frey (2010), *Urban road charge in European cities: A possible means towards a new culture for urban mobility?*, in: Report of the Joint Expert Group on Transport and Environment on urban road pricing schemes in European cities of the EU Commission.

Escuìn, D., Millán, C., and E. Larrodé (2012), *Modelization of Time-Dependent Urban Freight Problems by Using a Multiple Number of Distribution Centers*, Networks and Spatial Economics, vol. 12(3), pp. 321-336.

EUROSTAT (2011), *A fall in average vehicle loads. Average loads, distances and empty running in road freight transport – 2010*, Eurostat, Statistics in focus, 63/2011.

Herr, A. (2011), *Quality and Welfare in a Mixed Duopoly with Regulated Prices: The Case of a Public and a Private Hospital*, German Economic Review, Verein für Socialpolitik, vol. 12(4), pp. 422-437.

Hotelling, H. (1929), *Stability in competition*, The Economic Journal, vol. 39(153), pp. 41-57.

Hu, Z., Wei, C., Qing, L., and X. Fan (2014), *Competition with Online and Offline Demands considering Logistics Costs Based on the Hotelling Model*, Mathematical Problems in Engineering, vol. 12, pp. 1-13.

Köhler, U., and O. Groke (2004), *New ideas for the city-logistics project in Kassel,* In: E. Taniguchi & R. Thompson (Eds.), Logistics systems for sustainable cities: Proceedings of 3rd international conference on city logistics (pp. 321–332).

Lebeau, P., Verlinde, S., and C. Macharis (2015), *How authorities can support Urban Consolidation Centres? A review of the Best Practices*, In: Nectar Cluster 3: City Logistics and Sustainable Transport workshop.

Lindholm, M.E., and M. Blinge (2014), *Assessing knowledge and awareness of the sustainable urban freight transport among Swedish local authority policy planners*, Transport Policy, vol. 32, pp. 124–131.

Ma, C.A., and J. F. Burgess (1993), *Quality competition, welfare and regulation*, Journal of Economics, vol. 58, pp. 153-173.

Maggi, E. (2007), *La logistica urbana delle merci. Aspetti economici e normativi*, Polipress, Milano.

Marcucci, E.,and R. Danielis (2008), *The potential demand for a urban freight consolidation centre*, Transportation, vol. 35(2), pp. 269-284.

MDS Transmodal (2012), *Study on Urban Freight Transport*, DG MOVE European Commission.

Morana J., and J. Gonzalez-Feliu (2010), *Sustainable supply chain management in city logistics solutions: an experience's comeback from Cityporto Padua (Italy)*, Proceeding of the 3rd International Conference on Logistics and Information Systems, ILS 2010, Casablanca (Morocco), 14-16 April.

Muñuzuri, J., Larraneta, J., Onieva, L. and P. Cortes (2005), *Solutions applicable by local administrations for urban logistics improvement*, Cities, vol. 22(1), pp. 15-28.

Nagurney, A., Min, Y., Floden, J., and L.S. Nagurney (2014), *Supply chain network competition in time-sensitive markets*, Transportation Research Part E: Logistics and Transportation Review, vol. 70(C), pp. 112-127.

OECD (2014), *The Cost of Air Pollution: Health Impacts of Road Transport*, OECD Publishing.

Patier, D. (2006), *New concept and organization for the last mile: the French experiments and their results*, In: E. Taniguchi, and R. G. Thompson (Eds.), Recent advances in city logistics, pp. 361-374.

Regan A. C., and T. F. Golob (2004), *Trucking industry demand for urban shared use freight terminals*, Transportation, vol. 32(1), pp. 23-36.

Schoemaker, J., Allen J., Huschebeck M., and J. Monigl (2006), *Quantification of Urban Freight Transport Effects I* (BESTUFS I), 2006.

Silveira, G.J.C. (2005), *Market Priorities, Manufacturing Configuration, and Business Performance: An Empirical Analysis of the Order-Winners Framework*, Journal of Operations Management, vol. 23(6), pp. 662-675.

So, K.C. (2000), *Price and time competition for service delivery*, Manufacturing and Service Operations Management, vol. 2, pp. 392-409.

Trentini, A., Gonzalez-Feliu, J., and N. Malhéné (2015), *Developing urban logistics spaces: UCC and PLS in South-Western Europe*, Working Papers, Halshs-01214749, HAL.

Ville, S., Gonzalez-Feliu, J., and L. Dablanc (2010), *The limits of public policy intervention in urban logistics: The case of Vicenza (Italy) and lessons for other European cities*, In: 12th World Conference on Transport Research, pp. 13-20.

Voss, D.M., Page, T.J., Keller, S., and J. Ozment (2006), *Determining Important Carrier Attributes: A Fresh Perspective Using the Theory of Reasoned Action*, Transportation Journal, vol. 45(3), pp. 7-19.

Zhang, M., Janic, M., and L.A. Tavasszy (2015), *A freight transport optimization model for integrated network, service, and policy design*, Transportation Research Part E: Logistics and Transportation Review, Elsevier, vol. 77(C), pp. 61-76.

Zunder, T. H., and J. N. Ibanez (2004), *Urban freight logistics in the European Union*, European Transport / Trasporti Europei, vol. 28, pp. 77–84.