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Subadditivity and Contestability in the Postal Sector: Theory and Evidence

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Several studies have been conducted to analyze whether a regulation of the postal sector as a monopoly is actually efficient by examining its cost structure. The authors detected significant scale economies only in the delivery function and hence demonstrated a necessity for competition in the upstream operations. The primary purpose of this paper is to summarize the basic conditions of natural monopoly theory and to review the approaches and results of the studies dealing with this topic. Despite the importance of contestability in this context, previous literature concentrates only on the subadditivity aspect. The existence of economies of scale does not inevitably justify a governmental maintenance of the monopoly if the market is contestable. In this respect, further research is needed in order to account for contestability.

Keywords: Postal Sector, Scale Economies, Subadditivity, Contestability
JEL-Classification: D24, L51, L97, L22

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1 Introduction

Previous studies concerning the postal sector analyze whether the postal sector exhibits characteristics of natural monopoly. The aim is to test the existence of subadditivity in order to determine whether and how postal networks should be regulated. The existence of such characteristics in a postal network would have important policy implications. If the conditions of the natural monopoly are satisfied, it is preferable that only one supplier offers the postal services, because competition would lead to efficiency losses. In addition, there is a strong need for governmental regulation if only one supplier provides the postal services due to the risk that the monopolist charges excessive prices. However, it has been shown that there are postal operations where a competitive structure would be beneficial, because they do not exhibit characteristics of natural monopoly. The existence of a natural monopoly can be tested by analyzing the presence of scale and scope economies or subadditivity respectively. The question of the existence of a natural monopoly is relevant to decide whether market-entry is - due to efficiency reasons - desirable or not. However, Harold Demsetz has already in the sixties noted the importance of sunk costs - a major barrier to entry - for such issues (Demsetz 1969). Despite this importance, this aspect is not considered sufficiently in previous empirical investigations.

This paper focuses on the theory of natural monopoly applied to the postal sector and the econometric studies which have been conducted to examine this for the postal sector. The aim of this paper is to depict the principle ideas of the most relevant studies and to show the differences between the approaches of the different authors.

The paper is divided into two main parts. To understand the approaches, it is necessary to have a closer look on the theoretical background of this theme. A central question is what set of conditions are sufficient for cost subadditivity, and thus, for natural monopoly and how this can be applied to the postal industry sector. This issue will be discussed in the first part of this paper. The second and main part deals with the econometric studies which have been conducted to analyze the cost structure of postal service providers in different countries. In this part the approaches, the underlying datasets and the results of the studies will be reviewed and compared. Finally, the

results will be summarized and it will be shown that contestability - a central aspect in this context - is not considered in the previous research studies.

2 Theoretical Foundations of Subadditivity

The subadditivity concept is used to determine whether an industry exhibits monopolistic features. For an industry to be characterized as a natural monopoly, its cost function must be strictly subadditive over the entire relevant range of output (Baumol et al. 1988, p. 17). A natural monopoly is a market structure where it is efficient that a specific output vector is being produced by a single firm. Economies of scale and Economies of scope are the two major conditions associated with this issue. They help to determine whether competition should for efficiency reasons be introduced in a specific market and in which certain operational area this must be done. If, for example, an industry does not exhibit features of natural monopoly, it may be beneficial to encourage competition in this area. This section includes a theoretical discussion of the sufficient conditions for natural monopoly in the single- and multi-product case as the subadditivity concept can be applied to both cases.

In the **single-product case** global economies of scale are sufficient for subadditivity and thus for the existence of natural monopoly (Baumol et al. 1988, p. 22). Economies of scale denote the benefits from producing a higher amount of output. The existence of economies of scale therefore implicates that a firm could save costs when operating on a higher output-level. In other words, in terms of market structure scale economies imply that it is cheaper for one firm to produce a certain amount of a product than for two or more firms at a given output-level. Thus, the average costs of production diminish at higher output-levels, which is illustrated in figure 1 (Fritsch et al. 2007, pp. 184).

The intersection of the demand function D with the average cost function AC determines in this case the relevant market demand. It results from the declining average cost function that it is beneficial that the demanded amount X_2 is supplied by only one firm at the price of P_2. Each output quantity lower than X_2 can only be supplied at significantly higher average costs. If, for example, two firms supply the output X_2

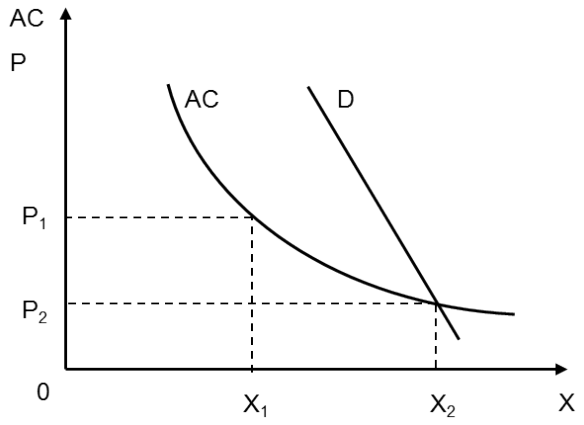

Figure 1: Average Costs in Natural Monopolies (Fritsch et al. 2007, p. 185)

together, each of them supplying the lower output X_1 at the price P_1, then the costs of producing one unit would be higher.

There are various reasons which can induce the existence of scale economies. A few examples of the most common reasons are a minimum amount of the input factors, economies of density, stochastic savings or learning curve effects.[1] The existence of one or more of these causes can lead to the existence of global scale economies and thus to a subadditive cost structure. With regard to industry structure, a subadditive cost structure would imply that it is cheaper for one firm to produce the whole output than for multiple autonomous firms to do so, whereas each produces a subset of the total quantity. Depicted formally, subadditivity of the cost function is given, if the following inequality is fulfilled:

$$C(\sum_{i=1}^{n} X_i) < \sum_{i=1}^{n} C(X_i).$$

Following this construction, the cost function $C(X)$ is subadditive, when for all output-subsets X_i (with $i = 1, ..., n$) less production costs arise, if only one supplier produces

[1] See Fritsch et al. 2007 for a closer discussion of the reasons for scale economies.

the whole amount. Thereby at least two subsets X_i must be greater than zero in order to satisfy this condition. The left side of this inequation represents the case that only one firm produces the whole output and the right side the case of a separated production by different companies (Fritsch et al. 2007, p. 188).

The extent of the economies of scale is usually measured by the elasticity of total costs with respect to the total output produced. This construct is defined by the following equation.

$$\eta_C = \frac{\Delta C}{C} / \frac{\Delta q}{q} = \frac{\Delta C}{\Delta q} \frac{C}{q} = \frac{MC}{AC}$$

The elasticity η_C indicates the change of the costs C, if the output q rises by one percent. If the value of this elasticity is less than one, it can be concluded that the industry exhibits substantial returns to scale. Thus it appears that - based on the duality between production and cost functions - the inverse term of this elasticity can be used to measure the extent of the economies of scale (Varian 1997).

$$S = \frac{1}{\eta_C} = \frac{AC}{MC}$$

The optimal size of an enterprise measured in terms of the output is following this definition at the scale economies value $S = 1$ where the average costs (AC) equal the marginal costs (MC) (Pindyck et al. 2009, pp. 329 and Baumol et al. 1988, p. 21).

The issue of subadditivity in the **multi-product case** was discussed in detail first by Baumol et al. in the eighties (Baumol et al. 1982 and 1988). Unlike the single-product case, scope economies play an important role in the multi-product case, because of the production of multiple heterogeneous commodities. In this context, declining ray average costs, which is the equivalent to declining average costs in the single-product case, is neither necessary nor sufficient for subadditivity of the cost function. Consequently, the sole consideration of scale economies will not help to determine whether

a natural monopoly is present in the multi-product case. Instead, it is important to analyze whether economies of scope are additionally present in the considered industry. Economies of scope denote the cost savings which result from the production of several different outputs jointly rather than separately. Thus, a combined production provides a significant cost reduction potential. However, the analysis in the multi-product case is more complex which is primarily founded in the different cost-functions of the products. Moreover, different amounts of the relevant market demand for the commodities complicate the analysis additionally. Similar to the single-product case, in the multi-product case several different reasons for the existence of economies of scope can arise. The most common reason is that the same input-factors can be used for the production of the different outputs. Using the example of a two-product industry, subadditivity can formally be defined as follows:

$$C(X, Y) < C(X, 0) + C(0, Y).$$

The left side of this inequation represents the costs in case of joint production of two heterogeneous products by a single firm. Contrary, the right side represents the case that these two products are supplied separately by two different firms whereas $C(X, 0)$ represents the costs of the sole production of the commodity X and $C(0, Y)$ the costs of the production of the commodity Y, respectively. If this inequation is satisfied, the two commodities X and Y should for reasons of efficiency be produced only by one firm, because the costs of producing them in combination are less than the costs of producing them separately (Fritsch et al. 2007, p. 192). To analyze whether subadditivity in a multi-product sector is fulfilled, it is necessary to examine whether the cost-function in the multi-product case exhibits mainly two particular features. Declining ray average costs and trans-ray convexity must be present in order that the cost-function in the multi-product sector exhibits subadditivity (Baumol et al. 1988, pp. 47). The combined presence of declining ray average costs and trans-ray convexity indicates the existence

of a natural monopoly, because it is technically efficient for only one firm to produce a particular mix of products. Declining ray average costs denote the cost savings of producing a higher amount of the product mix, whereas trans-ray convexity represents the scope economies in a multi-product case. Figure 2 illustrates an idealized average cost surface in which both subadditivity conditions, declining ray average costs and trans-ray convexity in a two-product case, are satisfied.

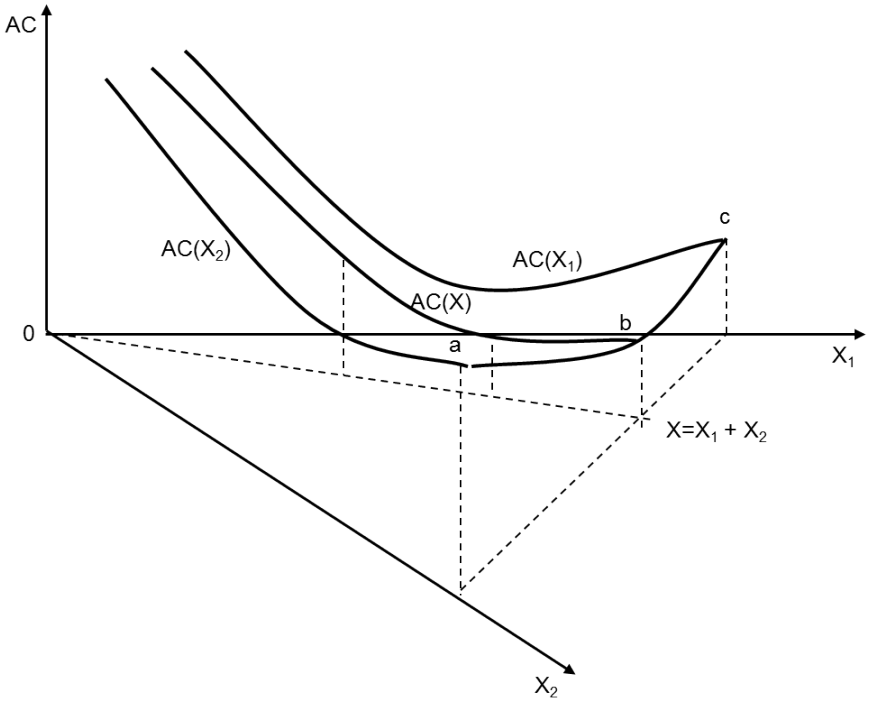

Figure 2: Declining Ray Average Costs and Trans-Ray Convexity (Modelled after Baumol 1982, p. 7)

The existence of **declining ray average costs** is the first characteristic of this cost surface. Since average costs cannot be defined in the multi-product case, the analysis of the average cost function curvature does not refer to the single products, but to whole output bundles whereas the proportions among the commodity quantities remain fixed. Thus, an arbitrary output vector or ray is chosen as a co-product in order to explore the effect of an equivalent elevation or decline of both products on the costs (Baumol

1982, p. 6). In figure 2 the dashed line between the two points 0 and X represents this ray and $AC(X)$ represents the associated average cost function of this product bundle. The essential features of the function $AC(X)$ in figure 2 are identical to those shown in figure 1.

The **trans-ray convexity** of the cost function illustrates the existence of economies of scope, which result from the combined production of both products X_1 and X_2. Trans-ray convexity can be applied to a multi-product firm and implies that it is less expensive for a single firm to produce a particular combination of different products than for different firms to produce them in isolation. This effect can be seen in figure 2 by considering the cross-section of the cost function. The sole production of either X_1 (point a) or X_2 (point c) causes higher costs than a combined production of both products (point b)(Baumol et al. 1988, pp. 48). The convexity of the cost function along all rays through the origin indicates trans-ray convexity and thus the existence of scope economies. However, if the effect of product-specific scale economies outweighs the effect of the scope economies, it is better for firms to specialize in the separate production of single goods. The joint presence of economies of scale and trans-ray convexity is sufficient for the presence of subadditivity in a multi-product industry and hence constitutes a natural monopoly.

As for scale economies the magnitude of scope economies can be calculated using an analogical measure. This measure quantifies the additional costs that occur, if two or more heterogeneous goods are not produced in common but separately. Formally, the degree of scope economies can be defined as follows:

$$SC_T(Y) \equiv \frac{[C(Y_T) + C(Y_{N-T})] - C(Y)}{C(Y)}.$$

The variable $SC_T(Y)$ can be interpreted as the percental change of the costs, if the whole product set N is not produced by only one firm. Thus, this measure quantifies the relative increase in cost which occurs, if the production of the two subsets T and

$N-T$ is separated. Such a separation of the production can lead either to an increase or a decrease of the total costs. Of course, there is the possibility that the separation does not have any effect on the total costs. These three cases are indicated by the measure $SC_T(Y)$, if it takes a value which is greater than, less than, or equal to zero respectively (Baumol et al. 1988, pp. 73). A combined production of all goods or services is thus less expensive, if the industry exhibits scope economies .

3 Characteristics of the Postal Sector

For a long time, usually only one mail service provider was in the postal sector, which operated under the constraint of governmental regulation. This regulated monopoly, however, has been already changed in several countries and many others will follow. To answer the question whether this change is truly efficient, it is necessary to have a closer look on the features of this industry, which is the focus of this section. In this context, the network character, the value creation chain and the production processes of this industry will be analyzed, which is necessary in order to test for the existence of subadditivity in this industry. After reviewing the features of the industry, the theoretical discussion of natural monopoly will be related to this specific setting.

Suppliers of mail delivery services represent a typical example for multi-product and multi-input enterprises. The firms operating in the postal sector serve a complex network of a large number of customers with different postal services using mail boxes, post offices etc. The main service consists of the carriage of mail although most firms provide further services e.g. the carriage and delivery of parcels and newspaper magazines. The network feature of this industry plays an exposed role because it is indispensable in order to provide an area-wide delivery of postal items. This is why the postal sector is counted among the network industries. However, compared to other network-industries the single elements of postal networks are not obvious by implication due to the fact that it is a transport network with common means of transportation used for the distances between the different locations of sender and addressee. In order to serve an area, a certain infrastructure for the collection, transport, and delivery of postal items need to

be developed in this area. The basic network elements are the mail boxes positioned in the area, the offices and counters, processing facilities, means of transportation, like road vehicles or airplanes, and most notably the employees in this branch especially those working in the delivery section. Figure 3 illustrates a basic model of a **stylized postal network** with its major elements.

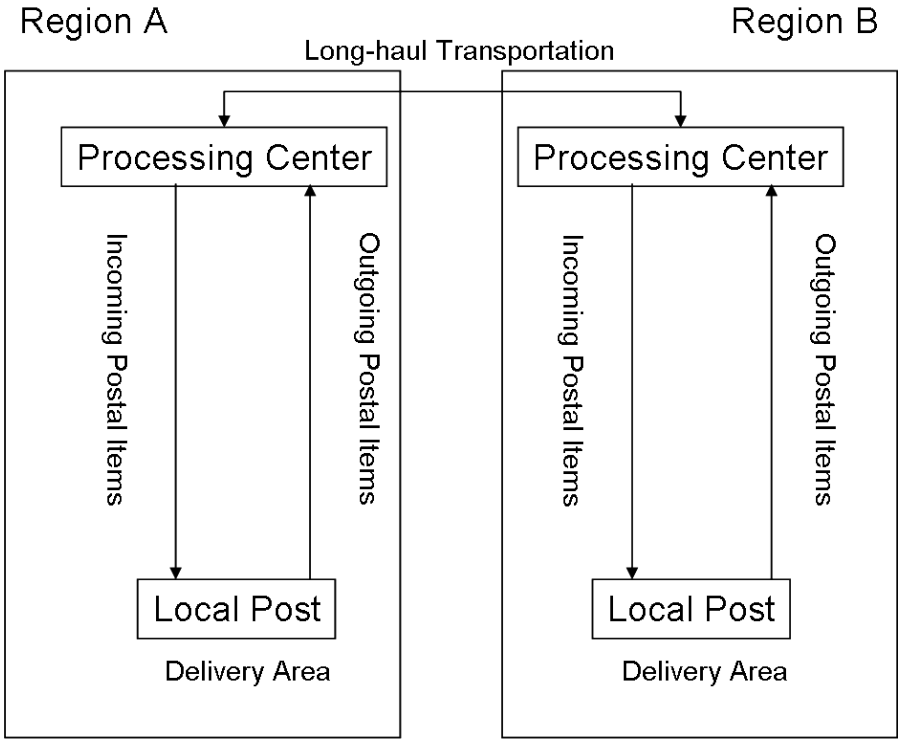

Figure 3: Simplified Stylized Postal Network (Wein 2009, p. 6 (similar))

The **value creation chain** of postal services encompasses mainly the four basic operations collecting, processing, transport, and delivery of postal items. The first step in this chain is to collect the mail. Typically, the postman collects the post which has been dropped into the letterboxes or receives it at the post-office counter. After the mail has been collected, it is transported (usually in trucks or vans) to the next processing centres where it is processed in order to deliver it to the right destination. Subsequently, the mail can be transported to another mail-processing centre located in the target region whereas one can distinguish between long-haul and short-range transport using

air or rail transportation facilities and trucking facilities respectively. When the mail has been processed, it is transported further to the delivery base where it is sorted according to delivery routes and then delivered by the postman by foot, car or bicycle. The delivery function is the most meaningful postal operation because the costs associated with providing this operation form the biggest portion among the total costs (Kruse et al. 2005, p. 18). This complex operation is typically divided into three components: route time, access time, and load time. Route time represents the time which is required to cross the route. These routes are in rural areas longer than in urban areas. In the next step the deliverer must departure from these routes to access the destinations, which is analogically called access time. Finally, load time represents the time required to drop the mail into the letter-box or to hand it out to the recipient (Rogerson et al. 1993, p. 114).

Mail service providers can operate on all value-added-steps mentioned above or only on selected ones (Christmann 2004, pp. 31). If a provider offers multiple or all value-added-steps, it is called vertical integrated. The degree of the vertical integration, hence, shows on how many steps the provider operates. Vertical integration can range from two to all value-added-steps (Schölermann 2005, p. 3). The opposite of the vertical integration would exist, if the provider operates on merely one step and obtains the rest of the services on the market. The decision of the vertical integration depends on its profitability. This is particularly the case, when the technological and organizational economies of scope are highly pronounced. More precisely, it is beneficial for a firm to offer multiple operations of the value added chain, if economies of scope exist between this operations, that is to say if it is cheaper to provide the specific operations combined than separated from each other. In very general terms, **coordination economies** are present in this case. Coordination economies may lead to the existence of subadditivity of the network as a whole, although the sole operations of the network do not exhibit features of natural monopoly (Rogerson et al. 1993, p. 113). The sources of natural monopoly can primarily be attributed to the sources of scope economies. Examples for this include the common usage of resources and transaction advantages through the

combination of two or more operations of the network.

Although an integrated network can be reasonable in an industry in certain circumstances, it can bring efficiency disadvantages about. It occurs, if one of the value-added-steps is a natural monopoly whereas the rest of the steps should be organized competitively for efficiency reasons. The vertical integration does not allow for the installation of competition in the other steps, so that efficiency potentials cannot be exploited. Applied to the postal sector, it was found that the delivery-operation exhibits natural monopoly features. Hence, the delivery operation should for efficiency reasons not be organized competitively whereas the other steps should be organized competitively.[2] The delivery-step is a **monopolistic bottleneck**.

The theory of natural monopoly discussed above can be applied either to the whole network or to single steps of it. In this context, it is to determine whether the network as a whole or some of its operations satisfy the sufficient conditions of the natural monopoly. Statistically this can be tested by estimating the cost-function and analyzing whether the cost-structure is subadditive as described earlier in this paper. The following chapter deals with different studies, which have been conducted to test for this.

4 Contestability

As has been shown in chapter two of this paper, the natural monopoly concept determines, whether - due to efficiency reasons - there should be only one supplier for a specific good or service in a market. Two major regulation issues emerge in this context. The first one refers to the question, whether it is necessary to regulate the market entry in order to prohibit or to allow entry into the market by potential competitors. The second one refers to the necessity of a price regulation so that - in case of the existence of a natural monopoly - the monopolist does not charge excessive prices or exploits consumers in any other way. The sole existence of subadditivity as discussed in chapter two does not automatically justify market regulation in either way. In fact, the combined consideration of both subadditivity and contestability sheds light on these regulation

[2]These findings result from different studies which will be discussed in chapter four of this paper.

issues (Fritsch et al. 2007, pp. 214). For this reason, the contestability concept will be examined more closely in this section in order to declare its relationship to subadditivity and its contribution for solving the regulatory issues.

The notion of contestability was primarily used by the American economist William Baumol in the eighties. This concept was developed in order to characterize markets by determining whether market entry is possible or not. Although this theory is applicable to a broad variety of market forms, it pertains primarily to markets with substantial attributes of natural monopoly. In short, a contestable market can be defined as one that can easily be entered by potential competitors and vice versa. Generally, it can be characterized by two main features: free and easy entry into and costless exit from the market (Baumol 1982, p. 3). **Free entry** indicates that potential entrants are not at a disadvantage compared with the incumbents. This refers to the three aspects: costs, consumer preferences and access to the required production technology. Furthermore, this refers to access to resourcing and selling markets. If potential entrants are in terms of these points at a disadvantage compared with incumbent firms, there would exist **asymmetrical market access barriers**. A **costless exit**, on the other hand, implies that firms can leave the industry without suffering a financial penalty (Griffiths et al. 2001, p. 83). In general, an exit from the industry is especially expensive, if the firms need to invest in so-called "sunk cost facilities". These are facilities which cannot be resold or rented without loss, if the firms intend to exit the market again. Consequently, the costs of acquiring such facilities cannot be recouped if the firm exits the industry. These costs are called **sunk costs** and the decision is in this case characterized as being **irreversible**, because it cannot be revised without a financial penalty (Bailey 1981, Baumol 1982 or Griffiths et al. 2001). For this reason, these costs are also called market access costs. It is important not to equalize sunk costs with fixed costs due to the characteristics of sunk costs mentioned above (Bailey 1981, pp. 178). Irreversible costs do represent fundamental barriers to entry and can hence be causative for lower contestability of a market. Indeed, sunk costs are only one example for barriers to entry.[3]

[3]Fundamentally, sunk costs do not represent entry barriers but exit barriers.

Apart form sunk costs, one can distinguish between numerous other barriers to entry. Due to the fact that sunk costs constitute the most crucial barriers, the analysis in this paper focuses on them.

A further necessary condition for contestability is that the potential entrants can enter the market before incumbents can react to this entry by reducing their prices. The **entry lag**, which represents the period necessary for entering the market, must be smaller than the **price adjustment lag**, which represents the period necessary for incumbents to lower their prices in response to the market entry and thus the increased competition in the industry (Shepherd 1984, p. 572).

Beyond that, the contestability concept helps to analyze the effect, which potential market entrants could have on the strategic behaviour of incumbent firms. It turns out that even the threat of new entry into the market by potential competitors could affect incumbents' behaviour in terms of price and output decisions, disciplining them to behave as would exist competition within the market. Consequently, contestable non-competitive markets behave in a competitive fashion forcing the incumbents to charge prices which equal their long-run average costs. Although market structure calls for a single seller, the threat of potential entrants asserts that they are without monopoly power. This effect is the higher, the easier it is to access and to leave the market. If the incumbent, notwithstanding, charges excessive prices, the potential entrants would enter the market and undercut the incumbent, being attracted by the possibility to earn profits in the industry. This behaviour is in literature known as "**hit-and-run entry**". **Hit-and-run entry** is likely, if sunk costs were not present, because the costs of leaving the industry become lower (Griffiths et al. 2001, p. 83). However, this implies that there is sufficient pricing flexibility in the industry, which is generally not a realistic assumption. Oftentimes, prices cannot be changed by implication. Strategically, market entries can be prevented by incumbents, if they do not exploit their monopolistic power in terms of pricing and thus the monopoly rents. Hence, the need for public intervention is in a contestable market dispensable. If on the contrary the market is characterized by irreversibilities, entry is not possible by implication, because firms outside the market are

at disadvantage compared with incumbent firms. Unlike the incumbents, the firms need to account for the sunk costs in their calculations. The threat of potential entrants could, moreover, force incumbents to be efficient in production. Inefficiency in production of incumbents could attract potential entrants who can produce a specific service or good to lower costs. The possibility to produce at lower costs allows them to charge lower prices.

In terms of regulation, it can be concluded that if there is a natural monopoly and the market is contestable at the same time, regulation becomes unnecessary. This refers to the former of the two regulation questions at the beginning of this section. Regarding the second question, it is to say that if the natural monopoly is not contestable, there is the risk that the monopolist charges excessive prices which makes a governmental price regulation indispensable. In addition, there is the possibility that the government needs to stimulate market entry, if a natural monopoly does not exist but there is no competition on the market, which becomes manifest in a small number of suppliers in the industry. This could arise from the absence of contestability and the fact that it is not possible without further ado. A contestable market without a natural monopoly, however, describes an accustomed competitive environment within the market. The following table sums the four possible combinations (Fritsch et al. 2007, pp. 214).

		Contestability (Irreversibility)	
		Yes	No
Subadditivity (Natural Monopoly)	Yes	Potential Competition	Monopolistic Bottleneck
	No	Competition	Too much Competition

Figure 4: Subadditivity and Contestability (Fritsch et al 2007, p. 215 (similar))

In summary, it can be said that the sole existence of a natural monopoly does not justify regulation. There is only necessity for regulation, if the natural monopoly is not contestable. The three conditions for contestability identified in this section are the following:

- Sunk costs must not be existent
- The entry lag must be smaller than the price adjustment lag
- There must not exist asymmetrical market access barriers, e.g. access to technology

Indeed, contestability can replace governmental regulation to a certain degree. Although the practical relevance of the contestability concept has been mistrusted in several studies, it appears that it is appropriate to describe the market structure and processes for many reasons. Figure 4 clearly demonstrates the dimensions, which must be considered in order to decide on regulation issues in postal markets. Both subadditivity and contestability must be included in the analysis.

The next section reviews the empirical studies which have been conducted to analyze whether the postal sector exhibits features of natural monopoly. In addition, it shall be analyzed, whether these studies accounted for the contestability concept.

5 Empirical Studies

In practice, the conditions of natural monopoly are difficult to prove. However, numerous empirical investigations shed light on the presence of these conditions in the mail delivery sector. This section reports the empirical investigations which have been conducted to determine whether there are scale and/or scope economies in postal services. The authors of the reviewed studies estimate for this purpose cost functions in order to analyze the existence of these economies or subadditivity respectively.

The theme of scale and scope economies is not only analyzed for the whole network but for single postal operations as well. The most econometric studies rely on an analysis of the postal delivery function, which results from the fact that the delivery function

makes the greatest portion of the costs within the postal operations. The amount of the studies which deal with the collection, transport, and processing of mail is significantly smaller. Most authors assume in their studies an operational structure resembling the one discussed in chapter 2 of this paper. For their analysis the authors proceed in their econometric studies as follows. First, the cost function of the postal delivery sector is being estimated. This estimated cost function is then taken to measure economies of scale and scope or to analyze the existence of subadditivity. In connection with their estimation the authors discuss the public policy implications of their theoretical and empirical results. Despite the importance of this topic for public policy, there is little evidence for it. The table at the end of this chapter lists the most important research efforts.

One of the first studies was undertaken by **Gupta and Gupta**. In their empirical investigations they analyze the existence of scale and scope economies in the operations of the United States Postal Service (USPS) using published postal data from 1961 to 1980. For this purpose they estimate the postal cost function on the basis of a translog cost function and account for labour, capital, transportation and space as factor inputs. The outputs were aggregated to two products due to limitations of the data. Based on this, they computed the scale economies estimates from the translog cost function and draw inferences regarding existence and intensity of scale and scope economies. The authors demonstrate in their study the existence of diseconomies of scale and economies of scope. The value for scale economies vary between 0.196 and 0.448. The striking variation in the estimates results from the sensitivity of the estimates of scale elasticities to capital cost changes, which are included in the dataset and in the estimation. This, however does not affect their main result that there are diseconomies of scale (Gupta et al. 1985).

One study in which the postal network has been examined as a whole (i.e. all operations in common) has been made by **Norsworthy et al.**. This results from the fact that the authors estimate the costs of Management Sectional Centers (MSCs) in their study. MSCs operate in the US on the whole postal network and are therefore responsible for collecting, processing, and delivering the postal items. The estimation has being processed

using data from 200 MSCs in 1984. As a functional form they employed a translog-function variable cost function. The authors could detect economies of scale to the amount of 10% in their estimations (Scale coefficient: 1.099) (Norsworthy et al. 1991).

Rogerson and Takis also analyzed whether the USPS postal operations exhibit scale or scope economies concentrating on the cost structure. They use for their analysis a simple model of the postal network of the USPS in which the postal services are divided into the components delivery, transportation and mail processing, which resembles the model discussed in section 3. To analyze whether there exist economies of scale, the authors choose the cost-elasticity of the output as a measure and derivate the measures from marginal cost-based rates. Moreover, in their study they used information from PRC data and several recent empirical studies of economies of scale and scope in the USPS. They calculated a value amounting to 35% for the delivery function.[4] They found out that there are scale economies in the delivery function but not in the processing and long-haul transportation which supports the hypothesis of Panzar (1991) (Rogerson et al. 1993).

In their analysis, **Bradley and Colvin** analyzed whether the postal delivery function is a natural monopoly testing it for subadditivity and estimating the degree of scope economies among individual products in this operational function. In their approach, they modelled costs as number of stops whereas they focused only on the access portion of delivery and ignored the loading time.[5] Furthermore, they implied in their model a direct and positive relationship between the volume of delivered items and the delivery costs. The authors used a non-linear least squares estimation in which the explanatory variables are the volume, the possible number of stops and the likelihood that an increase in the volume will generate additional actual stops which equal accesses to the delivery points. The data used in this study consists of mail volumes and delivery stops from a cross section of the USPS city carrier routes and encompasses a sample of routes from roughly 150,000 city delivery routes maintained by the USPS. The authors found

[4]This measure is discussed in section 2.

[5]The single components of the delivery operation are discussed in chapter 3.

both subadditivity of the delivery cost function and economies of scope. Moreover, they found in this study that there are scale economies in the transportation function. In their examination they detected only small effects for the long-haul transport with railroad or airplane estimating scale economies on average amounting to 1.03. They estimated larger effects for the road haulage which vary between 1.11 for long and 1.52 for short ranges (Bradley et al. 1994).

Cohen and Chu examined the impact of economies of scale using the example of the delivery function of the USPS. In their approach they first calculate the costs of the delivery function assuming that there is only one single firm, which offers this operation. In the next step they deviate from the assumption of the existence of a monopoly and calculate again the costs assuming that there are two identical firms, which are offering the delivery function (duopoly). Moreover, they assume that these two firms share the market equally and that each of them serves the entire country each delivery day. For their analysis, they disaggregate street delivery time in three subcomponents: a fixed route time, a partly variable access time depending on volume and a completely variable load time also depending on the volume.[6] The data used in this study encompasses a representative sample including data of street delivery costs, volumes and delivery point characteristics collected by the postal service. This data is observed every two weeks over a one year period for about 300 routes. As a result, the authors calculated higher costs in the duopoly case as in the single-firm case. This is deeply rooted in the fact that the fix costs accrue two times in the duopoly case, because each firm has to establish its own delivery network. From this, the authors inferred subadditivity in the cost structure of the US delivery function (Cohen et al. 1997).

The study of **Wada et al.** differs from the above-mentioned studies predominantly in two points. First, this study does not deal with the US postal market, but with the Japanese one. And second, the authors do not only concentrate on the delivery function, but also measure overall economies of scale, economies of scope and cost subadditivity. Therefore, the objective of investigation in this study is the postal network as a whole

[6]These components of the delivery function are discussed in section 3.

as it was proceeded in the study of Norsworthy et al. mentioned earlier in this section. They use two different multiproduct cost functions of the Japanese mail service whereas one is based on a usual translog cost function and the other on a generalized translog cost function and conduct the estimation using cross-sectional data from 1980 to 1994 encompassing 180 observation points. The total costs are estimated using the number of mail items, labour price input and goods price input. It results from this study that there are significant scope economies and overall scale economies lying between 1.03 and 1.06 in the Japanese postal market (Wada et al. 1997).

Cazals et al. undertook three major studies two of them dealing with the postal delivery function and one with the activities of post office counters. The study conducted in **1997** attempts to provide empirical evidence for subadditivity of the delivery process in the French postal services. For this purpose, the authors estimate both a parametric and a non-parametric model whereas they concentrate on the specifications and results of the parametric model. They use this parametric model to obtain a measure for returns to scale and to run simulation scenarios to test for subadditivity. For their estimation, they use data about mail volumes, labour quantities and environmental characteristics for a cross-section of 400 post offices in France in 1992. Moreover, information about types of delivery and on the working hours in the different activities is considered (Cazals et al. 1997).

In their study from **2001a** the authors also deal with the delivery activity. Their objective in this study is to analyze possible cost drivers for outdoor postal delivery activities and to explore size effects of the delivered items on the cost of outdoor delivery using French data. The authors define the characteristics of postal items (e.g. weight of the postal item) or environmental features as for example density of the delivery area as the appropriate cost drivers. This study uses index models to analyze these cost drivers. After estimating cost functions, measures of size effects are derived from the estimations. For their estimation in this study the authors use a fixed effects approach with a parametric specification of the cost functions and apply a within estimation procedure. The main variables in the equation are the outdoor delivery costs (measured

by the number of hours of labour worked in a week), the vector of output quantities and the density of the delivery area of each post office measured by the number of delivery points divided by the length of the route. The data used comes from a database of La Poste with data from 1994 to 1998 concerning around 9000 French delivery post offices. The five periods are considered for estimating the panel data model using a translog cost function. The cross-sectional analysis is processed using the data for the year 1998 because of the high quality. In both estimations the authors could find increasing returns to scale whereas the value for returns to scale in the fixed effects approach is higher than in the cross-sectional analysis. In short, the estimation with cross-sectional data yielded a scale economies measure amounting to 1.13 whereas the panel data estimation result amounted to 1.68 (Cazals et al. 2001a).

The third study of these authors is from **2001b** and deals unlike the other two mentioned with the front-office activities in the postal counters network of La Poste in France. The aim of the authors in this study is to obtain estimators of cost elasticity for all activities performed at counters in post offices by analyzing their cost function. For this aim, they decompose the production process of counters into front- and back office activities to obtain an estimate of the cost elasticity for the counters activities. The output of postal counters is measured by all operations and services offered to the customers at these counters. To derive the estimates, the authors choose an OLS regression and run different scenarios with the available data. In the first scenario the authors assume that two firms share the existing volume of mail whereas in the second scenario they assume that one firm takes all offices whose volume of mail is above the average and two firms share the remaining offices. In the third scenario one firm takes all offices where volume of mail is lower than the average and two firms share the rest of the post offices. This proceeding is redolent of the approach chosen by the authors Cohen and Chu in their study from 1997. The established models are used to compute an average amount of labour per post office. The obtained values are used by the authors to compare them with the values obtained by La Poste as a whole. The variables considered in these estimations are the cost of counter activity for a post office, sales and after-sales services,

financial services and the back-office activities for each post office. The data used to estimate the models comes from 9,168 post offices of the French public postal network observed in 1999. The authors found that on average counter activities are characterized by scale economies (80%). Furthermore they concluded that scope economies may also be present for the various front-office activities (Cazals et al. 2001b).

Bernard et al. published a study in which they explore reasons in order to explain the differences in delivery costs among different geographic areas. For this purpose they compare the delivery costs between two different countries: France and US. After presenting the demographic and postal delivery characteristics they develop the concept of postal density to account for these characteristics in the estimation. The authors choose two different approaches to derive the average costs. For the US they econometrically estimate a translog equation of street time while for France they estimate this variable using an engineering cost model. The dependent variable in the estimation is - as already mentioned - street time and the independent variables are the volume (pieces per address), the postal density and the number of addresses. The French data represent delivery data for La Poste which is available for each delivery area whereas each delivery area represents a postcode. The US data is from the City Carrier Cost System and the Rural National Count System and encompasses data from 39,737 rural routes and a stratified sample of 8,300 city routes for the year 1999. The authors found that volume is a more important cost driver at low postal density than at high postal density. The French postal density is higher at every quantile. At high postal densities the fixed costs are lower and thus the potential for scale economies is lower (Bernard et al. 2002).

A further study was published by **Gazzei et al.** dealing with the output elasticity of post office activities in Italy. The authors estimated several production functions in order to evaluate the role of universal service obligations (USOs).[7] To resolve the problem of the relation between unsaturation and scale economies the authors estimate

[7]Traditionally, the USO assures the provision of standard postal services at uniform and affordable quality and rates. This task was usually imposed on the monopolist (Crew et al. 1998).

production frontiers and choose the translog functional form because of its flexibility.[8] The overall scale economies are then derived through the proportionate change of all input factors and the corresponding change of the output. The authors choose four different models in order to estimate the scale economies and used data from 11,415 counters in Italy for the year 2000. They detected returns to scale in all offices regardless of their size. Furthermore, they found that the bigger the post office, the smaller the resulting unsaturation and therefore the smaller the potential scale economies. These results have been found in all estimations made by these authors (Gazzei et al. 2002).

Bradley et al. applied themselves to measuring scale and scope economies for the postal delivery function. Their aim was to obtain reliable measures of their magnitudes through modelling the USPS's method for optimizing its delivery network. For this purpose they specify a two-equation recursive model in order to reproduce the two-step delivery process of the USPS. First, the number of routes per zip code is determined and after that the time per route within the zip code. For their estimation they choose a quadratic functional form because of its ability to allow for increasing, constant or decreasing returns to scale and, besides, because of its ability to accommodate zero volumes in the dataset. The variables incorporated are prepared mail, cased mail and delivered mail. The dataset consists of daily observations on the total street time and volumes delivered. These observations are taken over a two week period equalling 11 delivery days in spring 2002. Moreover, the density variable has been added to the estimation to control for the geographic density of a zip code. The authors found that increases in delivered volume within a zip code lead to an increase in the number of routes required to provide the delivery service. An increase of the routes causes an increase in delivery time. In sum, the finding in this study is that the postal service exhibits characteristics of a natural monopoly. Not only scale and scope economies could be detected but also

[8]The translog function - a generalization of the Cobb-Douglas and CES functional forms - does not imply constant substitution-elasticities in all factor-combinations. Thus, this functional form allows for an approximation of the real cost structure by the development of a second-order Taylor series approximation. An application of this functional form is especially appropriate, if the real functional form is unknown (Schierjott et al. 1985, pp. 190).

coordination economies between the postal operations (Bradley et al. 2006).[9]

The last study to be mentioned is one made for the Swiss postal market undertaken by the authors **Farsi et al.** In this study they analyze the existence of scale, scope and density economies on the basis of a quadratic cost function using a cross-section dataset from the Swiss Post from 2004. The cost function for the delivery units of Swiss Post considers the two outputs mail and parcel and the two input factors labour and capital. Furthermore, the labour price (measured as the average annual salary of a full-time-equivalent delivery employee) and the capital price (measured as the ratio of the non-labour expenses to a measure of physical capital) are used for the estimation. Moreover, a variable representing the number of delivery points in the service area and a further one representing the number of affiliated local delivery units are included in the model. Additionally, dummy variables representing northern, eastern, western an southern regions are included in the model. The model is estimated using four different econometric specifications: ordinary least squares model, two different weighted least squares models and a multiplicative heteroscedastic regression model. The data used in this study consists of a cross-section of 328 mail delivery units operated by Swiss Post's letter section which are organized as 241 local delivery units and 87 regional centres. In this study, the authors could find empirical evidence for economies of scale, scope and density in all models whereas the last mentioned model yields the best results (Farsi et al. 2006).[10]

In summary, the authors have found in their empirical studies results indicating the existence of significant scale and scope economies in delivery. The results of the different investigations are uniform, but they differ from each other mainly in degree of scale and scope economies detected. The table set out in the annex summarizes the results of these studies. All studies have in common that they only consider the incumbent in their analysis but neither the actual nor the potential competitors on the market. This becomes manifest on the one hand in the models built for the analysis and on the other

[9]The notion of coordination economies has been clarified in chapter 3.

[10]There are some more studies which are not mentioned in this paper but they are indeed similar to those discussed here.

hand in the underlying dataset used to estimate the measures. Regarding the approaches there are differences in methodology chosen and in the underlying data. Consequently, a comparison between the different studies is due to these differences only possible to a limited extent. Most authors concentrate on analyzing whether scale or scope economies exist in individual postal operations ignoring the existence of coordination economies between the different operations. Furthermore, the widely spread use of the Translog-Specification is not without controversy.[11] To analyze whether the postal sector should be for efficiency reasons regulated as a monopoly, the authors test only for the existence of the conditions of natural monopoly. In their approaches the authors do not consider the contestability aspect.[12] Indeed, it has been shown in this paper that if a natural monopoly exists and the market is at the same time contestable, the market tends to result in an efficient outcome meaning that prices are not as high as in a monopoly which is not contestable. The same argument applies to the quality of the services. This results from the fact, that the incumbent in a contestable monopoly encounters a durable threat of potential competitors which forces him to set prices and quality level akin to the competition case. As a result, the market faces an efficient outcome and a legal regulation is dispensable. Thus, the existence of a natural monopoly is necessary but not sufficient to decide for legal regulatory measures. The different facets of the contestability aspect should rather be included in the analysis, which is certainly what Demsetz 1968 had in mind when he remarked that it is sunk costs and not economies of scale which constitute the barrier to entry that confers monopoly power (Demsetz 1968, pp. 55).

[11] That is why some authors choose the quadratic functional form, because - unlike the translog form - it can accommodate zero volumes in the dataset. Logarithmic forms like the Cobb-Douglas or translog would require additional adjustments.

[12] See section 4 of this paper.

6 Conclusions

The analysis in this paper focused on the exploration of the theoretical foundations of natural monopoly theory and reviewed the major empirical studies, which have been conducted to analyze this theme for the postal sector. The primary implications of the theoretical analysis refer to the question whether competition should be introduced in the postal market and in which concrete area of the postal network this should be done. Competition should be encouraged where the sufficient conditions of natural monopoly are not satisfied. In general, the authors have found that this holds for all postal operations except for the postal delivery function. However, it has been shown that it is indispensable to account for the contestability of a market in order to decide on regulatory issues. This aspect has not been considered adequately in previous studies. Moreover, empirical estimations only take data into consideration from the incumbent. In fact, information from actual and potential competitors of the incumbent must be increasingly included in the analysis. Another question to consider is how competition can be introduced in the specific operations if this is necessary. A separation of the postal delivery function could be for example a solution. However, this could lead to a disrupt of scope and coordination economies. Referring to these aspects, a great deal of research is still required.

7 Future Perspectives

One of the latest developments in the letter market is the initiation of the legally binding electronic letter. The electronic letter has already been successfully adopted in two European countries (Finland and Switzerland) and Germany is just about to adopt the German equivalent of this electronic letter called De-Mail.[13] This electronic letter differs from the accustomed e-mail in the sense that it requires a registration with identification card. Whether this innovation will be successful must be awaited. The fact is that a

[13]The Finnish version is called NetPosti and the Swiss one is called Inca-Mail both provided by the respective incumbent of the market.

success of this concept would have a huge impact for mail service providers. One of these impacts applies to the cost structure of the mail service provider since - as it was described in chapter three and four of this paper - the delivery costs represent currently the highest cost pool. The delivery operation disappears in case of the sending of an electronic letter.[14] A further impact is that the letter market is opened for competitors from the information and communications technology market.

[14]This does not apply to a hybrid form where the sent electronic letter is being printed, enveloped and hereupon delivered.

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8 Appendix - Summary of Major Research Efforts

Authors	Date	Title	Data	Region	Approach	Results
Gupta et al.	1985	Economies of Scale and Economies of Scope in the U.S. Postal Service	published postal data for 1961-1980	U.S.	estimation of postal translog cost function and inferences regarding scale and scope economies	economies of scale estimates between 0.196 and 0.448
Norsworthy et al.	1991	Productivity and Cost Measurement for the United Sates Postal Service	200 management sectional centres in 1984	U.S.	translog variable cost function	10% (Scale Coefficient: 1.099)
Rogerson et al.	1993	Economies of Scale and Scope and Competition in Postal Service	PRC data / several recent empirical studies of economies of scale and scope in the USPS	U.S., EU	derivation of measures of economies of scale and scope from marginal cost based rates	scale economies in delivery but no scope economies; returns to scale in some portions of the transportation function
Bradley et al.	1994	An Econometric Model of Postal Delivery	a sample of routes from roughly 150,000 city delivery routes maintained by the USPS	U.S.	non-linear least squares	mainly significant scope economies
Wada et al.	1997	Empirical Analysis of Economies of Scale, Economies of Scope, and Cost Subadditivity in Japanese Mail Service	cross-sectional data (180 observation points from 1980 to 1994)	Japan	usual translog cost function; generalized translog cost function	existence of scope economies and returns to scale between 1.03 and 1.06
Cohen et al.	1997	A Measure of Scale Economies for Postal Systems	CCS data for 1993 (8,000 route-level observations) and data from an unpublished paper (1988) based on UPU statistics which are based on communications with officials	U.S., UK	delivery function; comparison of the cost of providing delivery by a single firm with the cost of providing delivery by two identical firms	existence of economies of density; delivery costs are in the case of two firms are around 50% higher; value of scale USA 1988 (1993): 12% (13%) of the total cost; UK 1988: 17%; effects of economies of scale in delivery present significant barriers to entry
Cazals et al.	1997	Scale Economies and Natural Monopoly in the Postal Delivery: Comparison between Parametric and Non Parametric Specifications	cross section of 400 post offices in 1992	France	parametric and non-parametric	global elasticity of labor demand: 91%; 50%
Cazals et al.	2001a	An Analysis of some Specific Cost Drivers in the Delivery Activity	data from 1997 cross sectional data from 1998 (i), and panel data for the periods 1994-1998(ii)	France, EU	translog cost function	scale economies: 1.13-1.68 for France and 1.17 for EU-Countries; a 10% increase of postal density leads to a 2.7% decline of costs in France and 2.9% decline of the average costs in the EU-Countries; 0.885(i) and 0.594(ii)
Cazals et al.	2001b	An Econometric Study of Cots Elasticity in the Activities of Post Office Counters	data of 9,168 French post offices	France	OLS	80%

Bernard et al.	2002	Delivery Cost Heterogeneity and Vulnerability to Entry	data from 39,737 rural routes and a stratified sample of 8,300 city routes	France, U.S.	analysis of economies of density (US: translog-specification, F: engineering cost model)	postal density is low: France 23% and US 42%; postal density is high: France 13% and US 36%
Gazzei et al.	2002	On the Output Elasticity of the Activities of Post Office Counters in Italy	database of 11,415 counters in Italy	Italy	estimation of production functions: OLS over the whole sample (Model I); OLS over a subset of observations filtered by a stochastic frontier (Model II); like Model II but including quadratic terms in x (Model IIa); OLS over a subset of observations filtered with DEA model (Model III)	Model I: 1.2063; Model II: 1.2034; Model IIa: 1.2225; Model III: 1.1060; returns of scale in all offices between 10 and 25%
Bradley et al.	2006	Measuring Scale and Scope Economies with a Structural Model of Postal Delivery	data from 145 zip codes daily observations over a 2 week period (11 delivery days in the spring of 2002)	U.S.	two equations recursive structural model	scope economies measure: 1.662
Farsi et al.	2006	Economies of Scale, Density and Scope in Swiss Post's Mail Delivery	cross-section data from 2004 (information on 327 postal units)	Switzerland	quadratic specification to estimate measures of economies of scale, density and scope (between mail and parcels)(4 different models)	scale economies as well as scope economies

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