

# External economies of scale, government purchasing commitment and welfare improvements in the vaccines industry

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## Abstract

Some industries exhibit external economies of scale. In these cases, government intervention may generate increases of welfare through tax-subsidy programmes and advanced purchasing commitments. The issue is initially examined for the case of competitive markets in a long-run equilibrium. Then, taking the vaccines industry as an illustrative example, the paper proposes a suitable framework that is tailored to account for the most relevant characteristics of the real situation. The paper concludes advocating for intervention in competitive markets whenever economies of scale exist and implementing the policy is inexpensive.

## JEL Classification

D31; D64; H2; L13

## Keywords

External economies of scale; social welfare; tax-subsidy; income transfer; government intervention

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## Introduction

This paper illustrates that social welfare can be improved by introducing tax-subsidy programs in markets with external economies of scale. In addition to this, the paper examines the vaccine industry as an illustrative example in which the issue can be tested in practice. The aim of the paper is thus twofold: First, to develop a theoretical model for proving that, under certain circumstances, intervention of competitive markets through redistributive income policies always lead to Pareto-improving situations; second, to present an ad hoc theoretical framework with which to analyse the modern industry of vaccines. This will permit to apply some of the theoretical ideas of the paper to understand how the modern vaccines industry operates at the present.

Before we start the analysis, it is useful to record some basic theoretical principles. Generally, to achieve the highest possible level of welfare, economic theory recommends avoiding intervention in competitive markets. However, in the presence of externalities, correcting this type of market failure is prescribed for the market to deliver the best outcome in terms of welfare.<sup>1</sup> We are going to focus here on the external economies of scale affecting the supply-side of the market, which implies that the aggregate supply presents a negative slope in the long-run.<sup>2</sup> In particular, our attempt is to show how public policies may affect the market in a way that the price diminishes as the size of the industry grows, thereby permitting that all the economic agents expand their welfare level.

External economies of scale occur when a fall in unit costs arises from an expansion of an industry, without necessarily increasing the size of individual firms. Of course, this is possible because any number of firms may enter the market in the long run. From a theoretical point of view, economists largely acknowledge the compatibility of external economies of scale with competitive markets: Chipman (1970) provides interesting comments for the theoretical debate, while Meade (1952, p. 33) makes it clear that perfect competition can prevail under conditions of increasing returns insofar as the economies are external to individual firms.

This paper stresses the role played by external economies of scale in industries that, though being small in number, are nonetheless significant. Among the examples mentioned in the literature, some affect prominent markets.<sup>3</sup> The contribution of our analysis is the demonstration that, when discriminating among buyers is something possible, it is always realisable to design self-financing tax-subsidy schemes that expand the social welfare. In particular, the paper shows that government intervention in competitive markets may be welfare improving if external economies of scale are present.

As regards the related literature, some authors, like Thépot (2003), have tackled the issue within the context of imperfect competition. Our approach deviates from

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<sup>1</sup> Externalities are identified as one of the causes of market failures, whose distortions should be corrected through regulation. Previous studies have granted support to the view that government intervention is justified in front of externalities; See for instance: Chandra, Franck and Naqvi (2002), Helpman and Krugman (1985), and Panagariya (1981).

<sup>2</sup> Another possible approach adopts a demand-side perspective: The so-called network economies of scale result in individuals enjoying better market conditions as new consumers enter the industry. Although this is an interesting phenomenon, its analysis is left aside for the moment. Notice that, even if the type of economies considered here are basically linked to the supply, our approach involves both sides of the market, since tax-subsidy schemes do actually alter the elasticity of demand.

<sup>3</sup> Trade theorists, dating back to Graham (1923), had recognized the beneficial effects of real-locating resources to increasing returns to scale industries. See also Ethier (1982) in this regard. For a description of external economies in markets for cultural products, such as books, motion pictures, newspapers, etc., see Marvasti (1994). This paper explains how economies of scale derived from the population size lead to comparative advantage in trade. Besides, the presence of external economies of scale in the cotton industry is documented by Broadberry and Marrison (2002).

these studies in the fact that we examine perfectly competitive situations. Thépot (2003) showed that government intervention (through income transfers, for instance) is able to correct the market failures associated with imperfect competition and to restore the Pareto efficiency. Yet, Pareto-improving policies are easily explained when some degree of market power exists. This is due to the fact that regulations can generate greater efficiency by bringing the market equilibrium closer to the competitive one. In contrast with that, our results do not derive from correcting market failures associated with market power, but stem from the greater efficiency associated to the external economies of scale existing in certain industries.

Two seminal papers ought to be mentioned in this context. Aoki (1971) shows first that a tax-subsidy system makes the competitive market mechanism work efficiently in various economic environments with externalities. Then, Osana (1977) goes beyond and proves that, in a wide class of economies with Marshallian externalities, a Pareto optimum can be sustained by a competitive equilibrium with the aid of a tax-subsidy system. The conclusions reached by these two papers are beyond the scope of our study. Nonetheless, the model presented here deals with the topic in an original way and, more interestingly, permits concluding that self-financing tax subsidy policies can always be implemented so that they lead to Pareto-improving situations.

The relevance of the theoretical points described so far depends on the possibility of them to occur in real industries. Note first that our theoretical idea may grant support to the rationality of existing policies, such as granting home ownership vouchers in India or low-cost access to mobile phone technology in African countries. In particular, the applied section of the paper focuses on the case of the vaccines market, a peculiar part within the pharmaceutical industry.

The rest of the paper is organized as follows. Having motivated the topic in the introduction, Section 2 proposes a basic theoretical model for approaching the issue in a competitive framework in the long-run. Then, Section 3 accommodates the analysis to the vaccines industry. This new framework, tailored to account for the chosen example, is apposite to illustrate how our theoretical idea applies to existing industries. Finally, Section 4 summarizes the main conclusions of the paper.

## **The model**

The analysis of this section is carried out in a partial equilibrium context at the long-run. We examine the case of a linear demand, even if other functional specifications may of course be also valid.

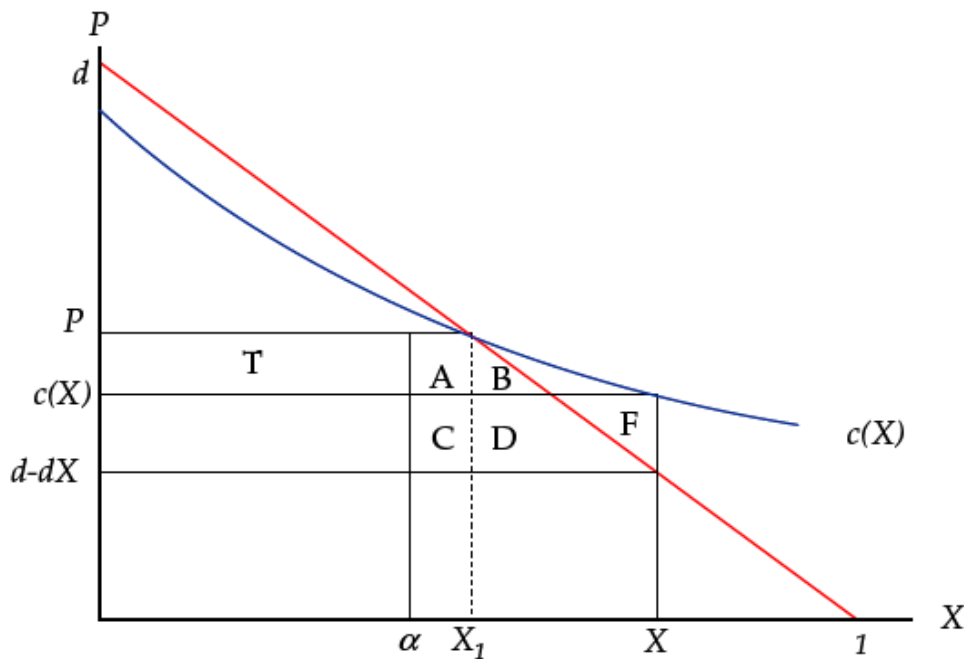
Consider a competitive industry with external economies of scale and identical firms. The total cost function of each firm is  $CT(x) = c(X)x$ , where  $x$  represents the production of the individual firm and  $X$  accounts for the total quantity traded in the industry. The market demand is given by  $P = d - dX$ , in which the quantity demanded at zero price has been normalized to one. Notice that neither linearity or normalization of the demand function implies loss of generality.

Following Thépot (2003), the analysis could be applied to a one-unit goods market. (This approach is particularly conclusive for highly-esteemed or indispensable goods; such as vaccinations, housing, or access to communications or education). We assume that a continuum of consumers with identical preferences exists whose disposable income for this good differs among them but is uniformly distributed. Thus, the consumers' reservation prices for one unit of good directly stems from

their income, leading to a linear demand in which  $d$  represents the income of the richest consumer.<sup>4</sup>

In this context, the implementation of redistributive policies by the government can lead to an equilibrium with a greater quantity and a diminishing price. Moreover, tax-subsidy schemes can be always devised in such a way that they preserve the welfare level of each individual under taxation, while improving the welfare of subsidized consumers. Notice that competitive industries bring forth no extraordinary profits to producers in the long-run, since individual firms have no market power. Accordingly, the total social welfare is composed of the surplus of consumers and the government solely. Figure 1 illustrates this situation, where the initial equilibrium is found at  $(P, X_1)$ .

Figure 1. Welfare improvements of self-financing tax subsidy programmes



The logic of the argument can readily be seen with the aid of the graphical representation. The government could be able to reduce the average production cost if it can provoke an expansion of the industry output, thereby lowering the costs of individual firms operating in a larger industry. Because of average cost pricing, the expansion of the industry leads to a lower consumer price at equilibrium.

But, how does the government expand the demand for the good while meeting a self-financing requirement? First, the government taxes high-reservation-price buyers, keeping the tax-inclusive price for these consumers at the initial price. Because the price faced by these consumers does not change, they do not gain or lose consumer surplus. The revenue generated through the taxes imposed on the first group of consumers is then transferred to low-consumer-surplus buyers in the form of a consumption subsidy, inducing new buyers to enter the market for the first time. Overall, subsidized buyers gain consumer surplus because of the lower market price, the subsidy, and the additional surplus accruing to new buyers. The

<sup>4</sup> The point is clear in the case of consumers who buy, at most, one single unit of the commodity. But the analysis is still valid as long as the tax charges consumption and the subsidy takes the form of a voucher. Besides, it is important to be aware now that Section 3 will adopt a different interpretation of the demand by representing the social willingness to pay involving both the private and public sector.

tax-subsidy scheme is more than a transfer from one group of buyers to another; it improves welfare because the average cost of the product has been lowered.<sup>5</sup>

A more formal description of the issue follows. If the final aggregate production is set at the level  $X$ , the total amount of the subsidy is defined by  $s = c(X) - (d - dX)$ , and the tax by  $t = P - c(X)$ .

The first step is then calculating the number of individuals,  $\alpha$ , who must be taxed to ensure that the programme is self-financing. (In terms of the areas of Figure 1, the self-financing constraint implies  $T = C + D + F$ ). Then, we solve  $(P - c(X)) \alpha = (X - \alpha)s$ , and obtain:

$$\alpha = \frac{s}{s+t} X \quad \text{or} \quad \alpha = \frac{c(X) - (d - dX)}{P - (d - dX)} X \quad (1)$$

The meaning of the previous result is straightforward. For the programme to be always affordable, the required number of individuals paying the tax is a fraction of the total number of final consumers, which is determined by the relative weight of the subsidy as shown in (1).

Besides, note that the drop in prices implies that none of the  $\alpha$  contributing consumers experience welfare losses once the programme has been implemented. Moreover, as far as  $X > X_1$ , any feasible self-financing transfer entails positive increases in social welfare, represented as  $A+B+C+D$  or  $T+A+B-F$  in Figure 1, and defined by the equation:

$$W(X) = (s+t)(X_1 - \alpha) + 2(s+t)(X - X_1) \quad (2)$$

Expression (1) has established the condition under which the transfer programme is costless for society and, hence, immediately affordable. Then, the second step is exploring how the size of the market  $X$  can be determined, which of course will depend on the target pursued by the policy makers.

### **Maximizing the social welfare**

Initially, we consider the case in which the government aims to establish the level of  $X$  that maximizes total welfare. In our model, the value that society assigns to consuming amount  $X$  is calculated as  $V(X) = d(X - 0.5X^2)$ . Defining the cost of producing  $X$  as  $CT(X) = c(X)X$ , and given that the government seeks maximizing

$V(X) - CT(X)$ , we get the first order condition for a maximum:

$$c'(X^*) = -\frac{s}{X^*} \quad \text{or} \quad X^* = \frac{d - c(X^*)}{d + c'(X^*)} \quad (3)$$

The optimal level  $X^*$  is such that it entails the greater increase in social welfare. This optimal value is only congruent for  $X^* < 1$ , and defines a maximum if the second order condition is verified, which in our model requires:

$$d + 2c'(X^*) + c''(X^*)X^* > 0 \quad (4)$$

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<sup>5</sup> In other words, to illustrate our point while avoiding unnecessary complications, the setting of the model adds a couple of assumptions: On the one hand, it assumes that the tax charges consumption and that the subsidy is granted in the form of a voucher. In this way, we prevent the effects of redistributive policies to affect other demands of the markets. On the other hand, we account for government intervention as the mechanism through which to exclude, from claiming and receiving subsidies, the individuals who can initially afford the good. There are other situations in which similar features may apply. For instance, it is surely the case if these two circumstances occur together: (i) uncertainty about the actual amount of the good that people will eventually consume; and (ii) the necessity to take a decision on the amount needed upfront, before and regardless of the willingness to pay that private consumers have in reality. The analysis of that type of situation is made in Section 3, where we examine the overall social demand for vaccines.

Note, however, that the fulfilment of the above inequality is not necessarily warranted. Among other things, the value of  $\alpha$  associated to  $X^*$  might be greater than  $X_1$ , implying that the solution is not feasible. But even then, the important fact remains that the government is always in the position to ensure welfare gains. This may be done by simply establishing the level of  $X$  associated with the maximum level of coverage in the industry; that is to say, by setting  $\alpha = X_1$ .

### **Maximizing the size of the industry**

Consider now that the goal of the government (rather than maximizing welfare) is providing access to the industry to as many individuals as possible. In accordance with this aim, the  $X_1$  initial consumers must be contributing consumers, which permits collecting the largest amount of funds to afford the greatest possible subsidy scheme. The problem is solved by equalizing  $\alpha$  to  $X_1$ , which determines the level of maximum coverage:

$$\hat{X} = \frac{s+t}{s} X_1 \quad (5)$$

The last expression is only consistent for values of  $\hat{X}$  that are always greater than  $X_1$ , since  $(s+t) > s$ . But again, it might also be the case that the full coverage of the market is reached for a number of contributing consumers smaller than  $\alpha = X_1$ . In other words, the size of the market imposes the feasibility constraint:  $\hat{X} \leq 1$ . Hence, if the value delivered in (5) does not satisfy the feasibility constraint, the optimal outcome instead has to be the corner solution defined by  $\hat{X} = 1$  and  $\alpha = s/(s+t)$ . Note anyway that the government always achieves its purpose of maximizing the coverage level. Whether the maximum feasible self-financing coverage is the one established in (5) or it is  $\hat{X} = 1$  is an incidental matter.

### **The vaccine industry: an illustrative example**

Some troubles may arise regarding the feasibility of implementing the tax-subsidy scheme and, more importantly, concerning the actual relevance of our theoretical argument in real markets. To come across these difficulties, this section adapts the theoretical elements to fit with the organisational aspects of the vaccines industry, which provides us with a suitable example.

The activities and features that characterise the vaccine industry are described, for instance, in Gordon and Samant (2008, p. 37): "The vaccine industry is composed of companies that are engaged in any of the following activities: research, development, manufacture, or sales, marketing and distribution of vaccines (...). Vaccine development is difficult, complex, highly risky, and costly and includes clinical development, process development and assay development." In accordance with that, to judge the existence of external economies one should examine the above mentioned activities one by one.

On one hand, these authors stress that, at the manufacturing stage, some production processes in the vaccine industry are scalable. This implies that a greater size of the manufacturing laboratory (or a larger market) would permit the unit cost per vaccine to be reduced. Nonetheless, it seems that other manufacturing activities are not scalable, thereby implying that the unit manufacturing cost of vaccines does not significantly decrease as the production volume expands.

On the other hand, unlike in the manufacturing processes, the existence of external economies of scale has to be recognised at the research and development stage. Precisely, Gordon and Samant (2008: 41) point out that the size of the market is a

crucial factor in developing new vaccines: 'A typical vaccine company will have several vaccine candidates in basic research... Those that are most promising in terms of technical feasibility, strong patent protection, and potential market size will be taken forward into development ... Thus, go/no go decisions must be made and market size is a major determinant of the choice between two candidate vaccines ... This system has worked extremely well for vaccines with large potential markets in the developed world when technical feasibility is demonstrated. It does not work for vaccines for diseases which exist predominantly in the poorer regions of the world ...; it works imperfectly for diseases of the developed world that affect only a relatively few persons because of geographic restriction.'

In any case, the existence of economies of scale in this type of industries should not be a surprise, insofar as the success in this business depends on research activities. Indeed, once the companies have assumed heavy investments and capital risks associated to research, a larger potential market makes more likely that the monetary return compensates for the initial expenses.<sup>6</sup>

In conclusion, we should accept that the cost of developing (and to some extent the cost of producing and commercialising) this type of medicines decreases along with the size of the market: the more units produced, the cheaper the average costs. Hence, the vaccines industry seems an appropriate context in which to apply the idea of this paper.<sup>7</sup>

In particular, we examine here the provision of vaccines – in 2009 and 2010 – for preventing influenza H1N1 to spread out. The large potential size of the market (1 billion doses of vaccinations were initially agreed, only in 2009, between the governments of the major economies and the industry) allowed for reducing the average production cost of the vaccine to about 2 € per unit. Besides, as Table 1 shows, a significant number of vaccines were donated to the less developed countries. Of course, should the aggregate demand of the market have a smaller size, the cost per unit of the vaccines would have been much larger. This is typically the case in markets where a large amount of investments (for the research and development of new patents) are needed and must be repaid by the consumers who eventually buy the product.

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<sup>6</sup> Gordon, Jerald and Vijay (2008, p. 42) explicitly explain that: 'Large companies believe that vaccines should be priced according to value to society; reduction in health care and related costs, relief from pain and suffering, and/or prevention of death, and that they should be rewarded for taking the enormous risks inherent in early vaccine development. Such prices far exceed manufacturing costs, but are essential to produce the revenue streams that allow vaccines to be competitive for Research and Development and manufacturing resources within large pharmaceutical companies, or that make biotech companies attractive investment opportunities.' A similar argument is given by Plotkin, Orenstein and Offit (2008, p. xxi) in the preface of their book: "This high cost [to bring vaccines from initial ideas to licensed biologicals] is a major disincentive for companies to develop new and improved vaccines. The requirement by major pharmaceutical companies for large markets to justify the expense of development means that many needed vaccines for geographically localized infections are not available."

<sup>7</sup> Further information on the matter can be found again in Gordon, Jerald and Vijay (2008 : 40-1): 'The role of large, full-service vaccine companies is predominantly in development. They engage in some limited basic research, significant amounts of targeted research regarding specific organisms, but the preponderance of activity is in clinical and process development. Expertise and sufficient personnel in process development and chemical engineering reside almost exclusively in such companies; there is no other resource for such development. Clinical development that will satisfy FDA standards is also done mostly by the large companies, funnelled through academia and contract research organizations... Many smaller organizations, often referred to as biotechnology companies, are engaged in vaccine research. They are often started by university scientists, supported by venture capitalists, and are capable of basic research on a vaccine idea. At this early state, they usually have limited capacity in process development and manufacturing, and none in distribution, sales, or marketing... Because of the large cost of adding new capacities and expertise, many biotech companies in advanced product development will opt to partner with large, full-scale companies. Although 60 or so small companies claim engagement in vaccine research and development, only about a dozen or so consider it a major activity.'

Table 1: Influenza H1N1: Vaccine Sales by Company and Donations

<i>Company</i>	<i>2009 Sales (Mill Euro)</i>	<i>Donors</i>	<i>Donations* (Mill doses)</i>
Sanofi Aventis	580	Sanofi Aventis	100
Glaxo Smith Kline	580	Glaxo Smith Kline	50
Novartis	580	8 Rich countries	50
Baxter	290		
MedImmune	290		
Sino Vac	116		
CSL	116		
Solvay	58		
Other Companies	690		
<b>Total</b>	<b>3300</b>	<b>Total</b>	<b>200</b>

\*The donations were made to WHO (World Health Organization). Sources: International meeting on the Influenza H1N1 Vaccine Market. Asociación Mémoire des Luttés ([www.medelu.org](http://www.medelu.org)) and KNOL unit of knowledge (<http://knol.google.com/k/influenza-2009-h1n1-vaccine-market>).

In summary, the vaccine industry is considered an illustrative example with which to analyze the theoretical ideas of this paper. Yet, given that the pharmaceutical companies must plan in advance the amount of vaccines they will produce, implementing self-financing programmes requires in practice that the governments approve the quantity before the private willingness to pay is revealed. This peculiarity, as well as the lack of information on some crucial aspects of the industry, has resulted in choosing the ad hoc framework of Section 3, which has been designed to account for the specific features of the case.

### ***A theoretical framework for the vaccines industry***

There is one critical issue that must be considered before applying our theoretical framework to the vaccines industry: to what extent does the vaccines industry behave as a competitive market? According to Gordon and Samant (2008), about one-half of vaccines for children in the US are exchanged in the private market. It means that there is a significant share of the market where the price-setting takes place under a free market regimen. The rest is then delivered through organizations of public character at a reduced price. And the share of free market tends to be smaller in Japan or in West European countries.

Moreover, the mentioned authors explicitly state that: ‘In addition to the burden of partial price controls, the vaccine industry is subject to intense regulation. It cannot sell products until the vaccine and the facility in which it is manufactured are approved by the FDA [Food and Drug Administration] or other regulatory authorities; each batch must be released by the appropriate regulatory agency; and the usage, and therefore market size, is largely determined in the United States by the CDC [Centers for Disease Control and Prevention] and in Europe by national regulatory authorities. Thus, the vaccine industry does not operate in a free-market environment, and its behaviour reflects these constraints.’ (cf Gordon and Samant, 2008: 42). But, even if the last quote seems to be indisputably asserted, the debate must remain still open if considering the sub-industry of research and development activities. Indeed, on the bases that little control is exerted on the initial research, and given the large number of small laboratories and other institutions involved in the matter, denying absolutely the competitive behaviour (at least in activities of this market) seems misleading.

Anyway, in front of these theoretical concerns, and due to lack of the necessary information, the applied section of this paper deviates from the preceding section. First, to deal with the theoretical analysis – while reflecting the manner in which the market operates in reality – in Section 3 we have taken into account the commitment of the governments to purchase certain amounts of vaccines. Typically, this agreement has to be made upfront, which is especially critical in order for the poor countries to enjoy cheaper prices.



The following text by Gordon and Samant (2008: 40-1) is very conclusive in this regard: 'To involve large companies in development and manufacturing of vaccines to meet needs such as bio-defense or health needs of poorer countries, incentives must be established to convince these companies that they should develop and manufacture such products. Such incentives might take the form of guaranteed purchase of certain volumes of a vaccine if specified standards are met, direct contracting by a government agency, or some other publicly funded mechanism. The use of Advanced Market Commitments to create a funding mechanism for vaccines needed in the developing world has been endorsed... Companies may be willing to engage in such work. Indeed, they may already have donated or sold vaccines at very low prices to poorer countries. Without special incentives, it is unrealistic to expect companies to engage in Research and Development on diseases that only, or predominantly, affect the poorer regions of the world.' In other words, advanced government commitments are essential to make it possible that new consumer gain access to the market, thereby increasing the total size of the industry.

Second, the issue cannot be treated with a single aggregate demand, as the subject seemed to require initially. But this difficulty is not such that it hinders other ways to address the topic in an appropriate manner. In particular, the domestic demand – that captures the overall willingness to pay of society – is going to be separately defined in each country by its respective government. Actually, governments are asked to commit themselves to buy vaccines at a price that is previously settled by the World Health Organization (WHO). The range of prices had previously been established according to the standard of living of the different countries.<sup>8</sup>

Another relevant aspect of the vaccines are the positive externalities attached to health goods and services. To account for this feature, the relevant demand in this case has to be defined as the overall willingness to pay of society, including the private consumers as well as the public sector.

In summary, and with the aim of exemplifying some theoretical ideas of this paper, the model is tailored to account for the following characteristics: (i) uncertainty on the private consumers' willingness to pay; (ii) public interest of the good under examination; (iii) commitment of the government to buy a certain amount of goods, which has to be pre-established upfront; and (iv) self-financing programmes in which the full-coverage (up to the quantity chosen by the government) is warranted by design.

### ***A suitable model for the vaccines domestic market***

Let us describe now the way in which our theoretical analysis can be modified to explain how the vaccine industry operates in reality. The new theoretical elements are proposed so that the framework became suitable for dealing with the available information displayed in Table 2.

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<sup>8</sup> According to the estimations of WHO, the price of the H1N1 vaccine would range between 2.5 and 20 US\$, depending on the economic status of the buyer country. The 2009 vaccine could be sold at around 10 to 20 US\$ in western economies, in the range of 5 to 10 in mid-level developing countries and in the range of 2.5 to 5 in the poor economies. The latter countries were extendedly funded by charities, global agencies, the World Bank, etc. Many policy makers agree that charging patients and countries by their ability to pay is better than providing free treatments.

Table 2: Pandemic Influenza H1N1: Vaccine Orders and Purchases (2009-2010)

Country	Price per unit (€)	Ordered Doses (Mill. units)	Ordered Market Value (Mill. €)	Purchased Doses (Mill.)	Purchased Market Value (Mill. €)	Used Doses (Mill.)	Used Market Value (Mill. €)
Spain	6.93	37	280.0	13	90.0	3	20.8
France	9.25			94	869.0	5	46.3
Germany	10.44			50	522.0	6	62.6
Netherlands	9.21			34	313.2	15	138.2
Italy	9.24			48	443.7		
Belgium	8.75			13	110.2		
UK	8.70	132	1148.4	48	417.6		
USA	8.67	251	2175.0	110	953.2		
Portugal	9.11	28	143.2				
Greece	9.18	24	220.4				
Australia	9.39	21	197.2				
Japan	9.19	53	487.2				
Canada	9.28	50	464.0				
Hungary	9.28	20	185.6				
Sweden	9.34	18	168.2				
Switzerland	9.37	13	121.8				
South Korea	9.37	13	121.8				
China	5.80	65	377.0				

Sources: International meeting on the Inuenza H1N1 Vaccine Market. \Asociación Mémoire des Luttes" (www.medelu.org) and KNOL unit of knowledge (<http://knol.google.com/k/inuenza-2009-h1n1-vaccine-market>).

In this regard, two important elements are going to be treated differently, as compared to Section 2:

1. The long-run supply of the industry is now replaced with a function capturing the cost that society abides, due to the government commitment to purchase a fixed amount of vaccines. This function is then defined, for each country, as:

$$PX = d, \quad \text{for } X \in (0, d / \bar{p}) \tag{6}$$

where  $\bar{p}$  is the final price (per unit of vaccine) actually paid.

2. Regarding the domestic demand, we focus here on the public sector, because it is the government who makes the purchasing decision. The relevant demand in each country is therefore defined as the government willingness to pay for the vaccines. Besides, we assume that the government plays a subsidiary role, thereby accounting for the fact that some individuals are willing and able to afford themselves the cost of the vaccination.

In accordance with that, we consider the government net willingness to pay as the result of taking into account the following two elements:

(a) The social willingness to pay for the vaccines provision, as revealed by the sum paid upfront by the government (to account for the number of citizens that the government considers should be surely protected). Notice that the population is free to buy or not the vaccine at the price per unit shown, for 18 countries, in Table 2. But, these people who initially decide not to buy the vaccine will eventually get free access to it, up to the level established by the ex ante decision of the government. The issue can thus be considered a subsidized consumption programme that ensures that a certain proportion of population joins the vaccination campaign.

(b) The private willingness to pay for vaccinations, which implies alleviating the net amount of money spent by the government in this matter. Of course, a large private consumption manifests a big private willingness to pay. And hence, given the subsidiary role granted to the government, the resulting public willingness to pay becomes smaller.

The conjunction of these two elements, by subtracting the latter one (b) from the former (a), yields the effective public demand function, which we treat as the relevant domestic demand in each country (derived from the decision problem of the government):

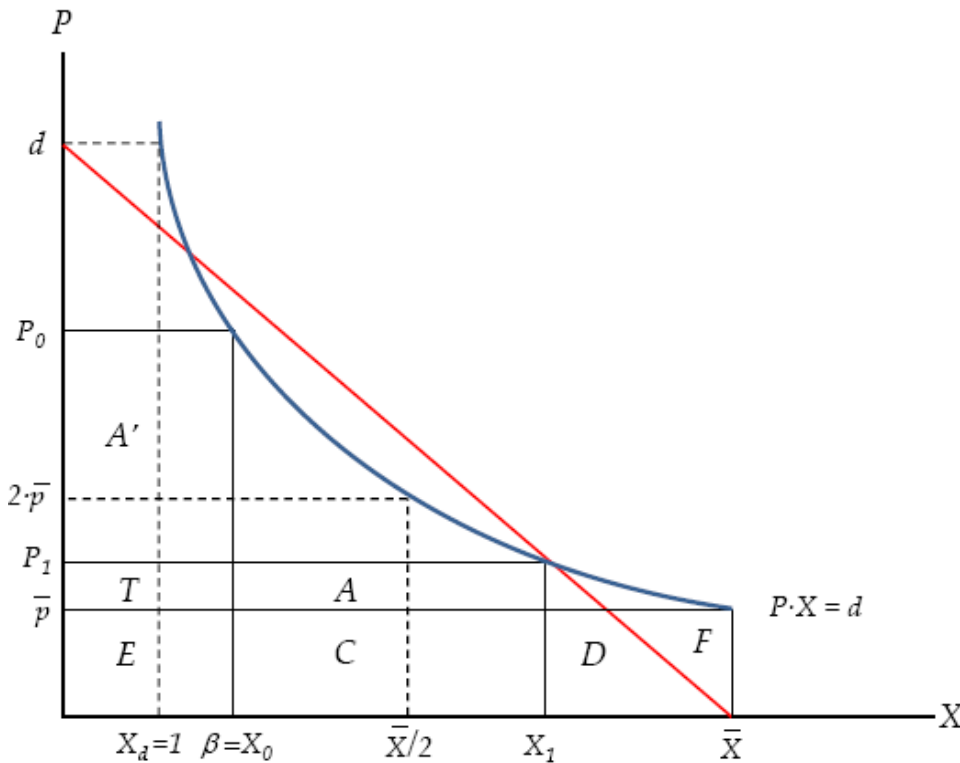
$$P = d - \bar{p}X, \text{ or } X = \frac{d - P}{\bar{p}} \tag{7}$$

The interpretation of this demand is straightforward. The government is ready to pay upfront a sum so high as to ensure sufficient vaccines freely available (for the proportion of the country's population that was previously chosen). However, given its subsidiary role, the government's willingness to pay decreases along with that of private consumers. But of course, the fact is that the private willingness to pay is known only after the payment for the vaccines has been made.

Obviously, the above ad hoc description deviates from the framework developed in Section 2, implying that the graphical representation is also different.<sup>9</sup>

To understand the particularities of this new approach, Figure 2 illustrates the situation.

Figure 2: A suitable framework for the vaccines domestic market



Among other features, the new framework implies that the full-coverage level is internally warranted by the model, regardless of the willingness to pay of private consumers. It is always the case, provided that the intervention of the government makes that any value given to the “old”  $\alpha$  (as characterised in Section 2) is compatible with a self-financing programme.

<sup>9</sup> In fact, it may be argued that – within this framework – little difference exists between the costs and the willingness to pay. It is actually true that the specificities of this peculiar approach introduce some difficulties to rightly interpret the resulting demand and supply functions.

To avoid misunderstandings with the notation, in Section 3 we use  $\beta$  to express the amount of vaccines that private consumers are willing to buy. Note further that, in Figure 2, the areas no longer represent the social welfare associated to consumer surplus (as it was the case in Section 2), since the functions here have a different meaning. Similarly, Table 3 shows the values of the relevant parameters and functions representing the situations of the countries for which sufficient information was available.

Table 3: A Model for Influenza H1N1 Vaccine Market by Countries

Country	d	$\bar{X}$	$\bar{p}$	Cost Function	Demand Function
France	869.0	94	9.2447	$p X = 869$	$p = 869 - \frac{869}{94} \cdot X$
Germany	522.0	50	10.440	$p X = 522$	$p = 522 - \frac{522}{50} \cdot X$
Netherlands	313.2	34	9.2118	$p X = 313.2$	$p = 313.2 - \frac{313.2}{34} \cdot X$
Spain	90.0	13	6.9231	$p X = 90$	$p = 90 - \frac{90}{13} \cdot X$

Perhaps the most relevant feature of the new characterisation – of the model in Section 3 – is the fact that full-coverage is always achieved. For this to be understood, consider that the size of the vaccines market – as far as the public interest is concerned – is given by the fixed amount determined ex ante by the government. In this context, the actual amount of vaccines that private consumers purchase is denoted by  $\beta$ . But, of course, the amount purchased by private consumers, even if consistent with a full-coverage situation (as is the case for any other value of  $\beta$  in this framework), is not necessarily the optimal choice.

In addition to full-coverage, it is easy to see that the model – in its current version – always delivers self-financing outcomes, insofar as public resources give support to the programme for it to be always affordable. A simple look at Table 4 permits easy verification of this feature, by cross checking the values of the relevant areas in Figure 2. Of course, the first identity that holds is:  $d = E + T + A' = E + C + D + F$ .

Table 4: Self-financing Programmes. Value of the Areas in Figure 2 by Countries

Country	T + A	D + F	T + A'	C + D + F	E + T + A'	$\frac{E + C + D + F}{D + F}$
France	9.3452	9.3452	822.7766	822.7766	869.0	869.0
Germany	10.6576	10.6576	459.3600	459.3600	522.0	522.0
Netherlands	9.4999	9.4999	175.0235	175.0235	313.2	313.2
Spain	7.5577	7.5577	69.2308	69.2308	90.0	90.0

Then, in Table 5, we summarize the main results from sorting out some relevant values of the model. The table reports the pair of values associated with various relevant values of the consumption levels of vaccines. For instance, if we consider the situation actually chosen by private consumers,  $\beta = X_0$ , it comes out that the effective cost per unit of the vaccines eventually used is as high as  $P_0$ . Given the small demand for vaccinations that Table 4 reports (as deduced from the amount chosen by final private consumers in each country),  $P_0$  takes extremely high values. Of course, if we consider the so called full-coverage situation  $\bar{X}$ , the price per unit is equal to the price per unit actually paid,  $\bar{p}$ .

Table 5: Quantities and Prices. Influenza H1N1 Vaccine Market

Country	$B = X_0$	$p = P_0$	$X = \bar{X}/2$	$P = 2\bar{p}$	$X = X_1$	$p = P_1$	$X = \bar{X}$	$P = \bar{p}$
France	5	173.8	47.0	18.49	92.9891	9.3452	94	9.2447
Germany	6	87.0	25.0	20.88	48.9792	10.6576	50	10.4400
Netherlands	15	20.9	17.0	18.42	32.9687	9.4999	34	9.2118
Spain	3	30.0	6.5	13.85	11.9083	7.5577	13	6.9231

Notice that, according to our assumptions, the payments eventually made by final consumers alleviate the government expenses in vaccines. If considering the case of  $\beta = X_0$ , which corresponds to the number of vaccinations actually consumed, we get that the consumers pay the amount  $\beta\bar{p}$ , and the government subsidizes the rest:  $\beta(P_0 - \bar{p})$ . Naturally, the total amount of aggregating the public and public payment is equal to  $\beta P_0$ .

But the government must set upfront the number of vaccines, and it chooses  $\bar{X}$ .

At this larger amount, the effective price per unit becomes cheaper (the price drops from  $P_0$  to  $\bar{p}$ ), which allows new consumers to gain access into the vaccine market. Again, the total expenses are afforded thanks to both the willingness to pay of private consumers:  $\beta\bar{p}$ ; and of the government:  $(\bar{X} - \beta)\bar{p}$ . Hence, the overall payment in this case is given by  $\bar{X}\bar{p}$ , which, by design of the model, is equal to  $\beta P_0$ .

Finally, some comments may help to understand the logic of the model in its ad hoc version. To this aim Table 6 reports the calculations of estimating the effective cost per unit that the government affords at different possible values of  $\beta$ . The results of this exercise are computed with respect to both the number of vaccines eventually purchased by the consumers and with respect to the total available units agreed upfront by the government.

Table 6: Effective Government Cost per Unit (dependent on the chosen  $\beta$ )

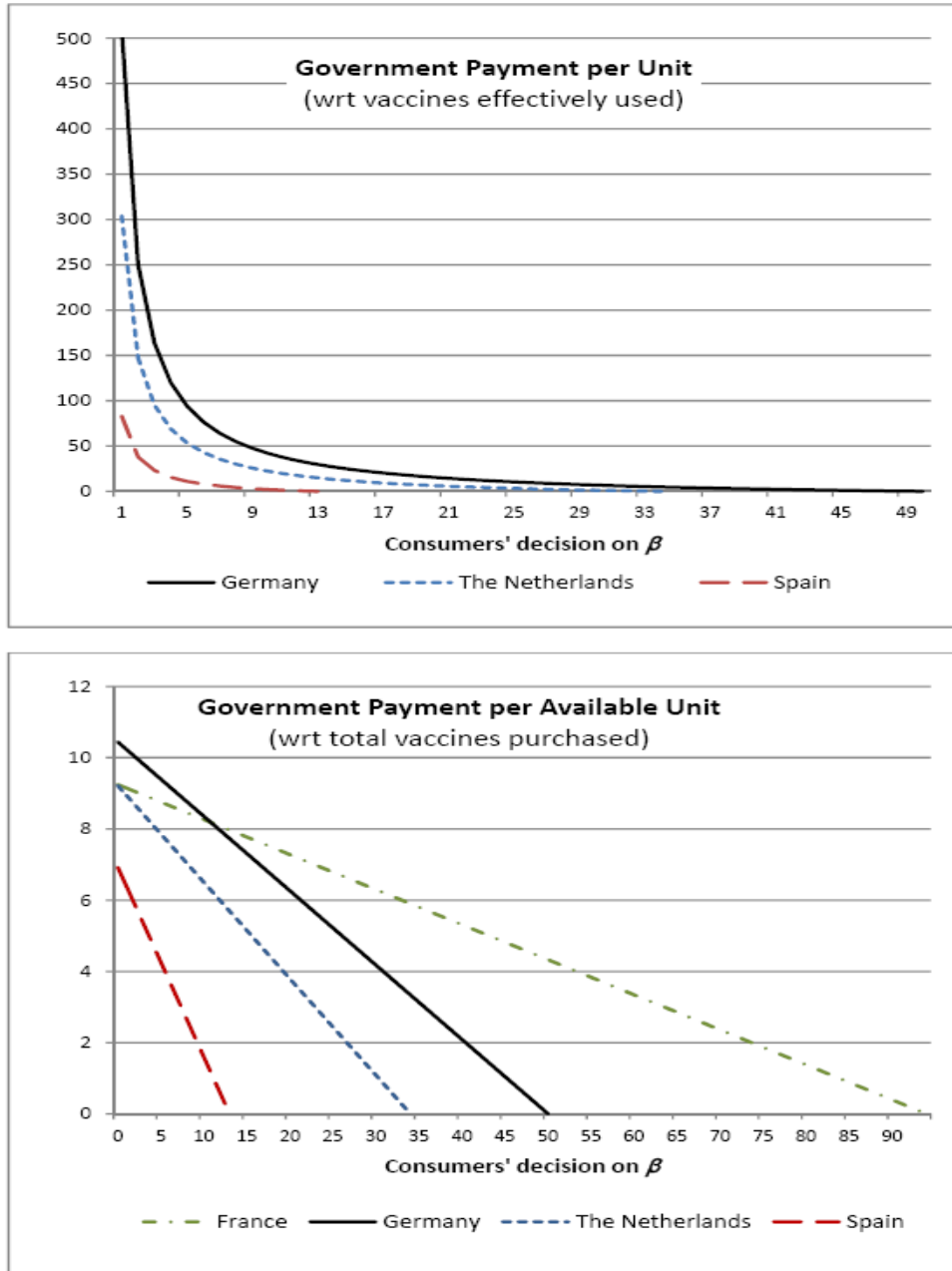
$\beta$	wrt Purchased Units by Consumers				wrt Total Available Units			
	France (€/unit)	Germany (€/unit)	Netherlands (€/unit)	Spain (€/unit)	France (€/unit)	Germany (€/unit)	Netherlands (€/unit)	Spain (€/unit)
0	$\infty$	$\infty$	$\infty$	$\infty$	<b>9.24</b>	<b>10.44</b>	<b>9.21</b>	<b>6.92</b>
1	859.76	511.56	303.99	83.08	9.15	10.23	8.94	6.39
2	425.26	250.56	147.39	38.08	9.05	10.02	8.67	5.86
3	280.42	163.56	95.19	<b>23.08</b>	8.95	9.81	8.40	<b>5.33</b>
4	208.01	120.06	69.09	15.58	8.85	9.60	8.13	4.79
5	<b>164.56</b>	93.96	53.43	11.08	<b>8.75</b>	9.40	7.86	4.26
6	135.59	<b>76.56</b>	42.99	8.08	8.65	<b>9.19</b>	7.59	3.73
7	114.90	64.13	35.53	<b>5.93</b>	8.56	8.98	7.32	3.20
8	99.38	54.81	29.94	4.33	8.46	8.77	7.04	2.66
9	87.31	47.56	25.59	3.08	8.36	8.56	6.77	2.13
10	77.66	41.76	22.11	2.08	8.26	8.35	6.50	1.60
11	69.76	37.01	19.26	1.26	8.16	8.14	6.23	1.07
12	63.17	33.06	16.89	0.58	8.06	7.93	5.96	0.53
13	57.60	29.71	14.88	0.00	7.97	7.73	5.69	0.00
14	52.83	26.85	13.16		7.87	7.52	5.42	
15	48.69	24.36	<b>11.67</b>		7.77	7.31	<b>5.15</b>	
16	45.07	22.19	10.36		7.67	7.10	4.88	
17	41.87	20.27	<b>9.21</b>		7.57	6.89	4.61	
18	39.03	18.56	8.19		7.47	6.68	4.33	
19	36.49	17.03	7.27		7.38	6.47	4.06	
20	34.21	15.66	6.45		7.28	6.26	3.79	
21	32.14	14.42	5.70		7.18	6.06	3.52	
22	30.26	13.29	5.02		7.08	5.85	3.25	
23	28.54	12.26	4.41		6.98	5.64	2.98	
24	26.96	11.31	3.84		6.88	5.43	2.71	
25	25.52	<b>10.44</b>	3.32		6.79	5.22	2.44	
26	24.18	9.64	2.83		6.69	5.01	2.17	
27	22.94	8.89	2.39		6.59	4.80	1.90	
28	21.79	8.20	1.97		6.49	4.59	1.63	
29	20.72	7.56	1.59		6.39	4.38	1.35	
30	19.72	6.96	1.23		6.29	4.18	1.08	
31	18.79	6.40	0.89		6.20	3.97	0.81	
32	17.91	5.87	0.58		6.10	3.76	0.54	
33	17.09	5.38	0.28		6.00	3.55	0.27	
34	16.31	4.91	0.00		5.90	3.34	0.00	
35	15.58	4.47			5.80	3.13		
36	14.89	4.06			5.70	2.92		
37	14.24	3.67			5.61	2.71		
38	13.62	3.30			5.51	2.51		
39	13.04	2.94			5.41	2.30		
40	12.48	2.61			5.31	2.09		
41	11.95	2.29			5.21	1.88		
42	11.45	1.99			5.11	1.67		
43	10.96	1.70			5.02	1.46		
44	10.51	1.42			4.92	1.25		
45	10.07	1.16			4.82	1.04		
46	9.65	0.91			4.72	0.84		
47	<b>9.24</b>	0.67			4.62	0.63		
48	8.86	0.44			4.52	0.42		
49	8.49	0.21			4.43	0.21		
50	8.14	0.00			4.33	0.00		
51	7.79				4.23			
...	...				...			
...	...				...			
94	0.00				0.00			

The “Effective Government Cost per Unit” function is dependent on the values of  $\beta$  that the consumers choose in the end. Besides, its definition differs depending on the reference with respect to which the calculation is expressed. We denote as  $P_{\beta}^g$  the cost that the government pays per unit of the vaccines that were effectively used by the consumers; and by  $P_{\beta}^g$  the government cost per unit of available

vaccines. The respective definitions of these functions are given by the following equations:

$$P_{\beta}^g = \frac{1}{\beta}(d - \bar{p}\beta) \text{ and } P_{\bar{X}}^g = \frac{1}{\bar{X}}(d - \bar{p}\beta) \quad (8)$$

Figure 3: Government cost per unit (wrt available and purchased vaccines)



The outcomes resulting for different values of  $\beta$  are reported in Table 6, and the same findings are also illustrated by means of two diagrams in Figure 3. A simple inspection of the data confirms that the minimum possible payment made by the government corresponds to the case in which  $\beta = \bar{X}$ . It cannot be different because, at this level, the  $\beta$  chosen by the consumers is equal to the total amount that the government purchased through the advanced market commitment.

An interesting matter is, perhaps, to calculate the threshold at which the value of  $\beta$  permits the government subsidy to be smaller than the price actually paid by the consumers. For this purpose, we propose a transformation of the first function in expression (8), which leads to:

$$P_{\beta}^g = \frac{1}{\beta}(d - \bar{p}\beta) = \frac{\bar{X} - \beta}{\beta} \bar{p} \quad (9)$$

Notice that by definition  $\beta < \bar{X}$ . By looking at the new form of function  $P_{\beta}^g$ , it is obvious that  $\beta = \bar{X}$  leads to the minimum value of the function:  $P_{\beta}^g = 0$ . But the question now is to find the value of  $\beta$  at which it starts to hold that  $P_{\beta}^g < \bar{p}$ . It is very easy to prove that it happens for any  $\beta > \bar{X}/2$ . This result, even if trivial, is highlighted in Table 6 by using bold and italic characters.

## Conclusion

The main idea of this paper refers to competitive industries with external economies of scale. In this context, we have shown that, unless the policy involves implementation costs that are too heavy, adopting well-planned tax subsidy programmes can always have Pareto-improving effects.

First, the paper has examined the impact – in terms of social welfare – of introducing tax-subsidy programs in markets characterized by the presence of external economies scale. Then, the analysis has focused on studying the vaccine industry as one appropriate example for illustrating the theoretical aspects.

From the theoretical analysis, the presence of external economies of scale permits that tax-subsidy schemes may always be designed in such a way that they improve the welfare status of all the economic agents involved in the matter. Besides, the setting of the model has been designed for the redistributive policy to be self-financing. Moreover, if the transfer is properly arranged, it can always lead to Pareto-improving situations. We venture that this theoretical possibility may help explaining the success of existing programs that provide vouchers to low-income individuals. This is because none of the incumbent consumers experience losses in welfare, whereas a number of new individuals gain access to the market by purchasing the good at a subsidized price.

Our approach involves both the demand and the supply side of the market, since the external economies affect the shape of the aggregate supply, while the tax subsidy programme influences the effective demand function. In this context, we have proved that intervention is capable of increasing the total amount of trade in the industry while the equilibrium price declines, thereby having Pareto-improving effects. Naturally, this is the case unless the cost of implementing the policy was too high. Our result reinforces the idea that intervention could be preferred in front of externalities, even under the assumption of perfect competition.

To illustrate a real example, this paper has examined the case of the vaccine for the pandemic influenza H1N1. Even if the market of vaccinations was perfectly apt to examine the relevance of external economies of scales, due to the limited available information, we have adopted in Section 3 an approach that deviates from the original framework of Section 2. In the latter approach, two main features have been accounted for: (i) uncertainty about the amount of good that is demanded and (ii) the requirement that the government should take a decision (on the quantity to be purchased) *ex ante*, regardless of the actual private demand. After having described the behaviour and regulation of the modern industry of vaccines in reality, the paper shows that it is possible to implement better public practices to make the provision of vaccines more efficient and feasible for broader geographic areas.



In summary, the main idea of this paper is taking advantage of the external economies of scale to improve the welfare of all the agents of a particular market. Our study ultimately implies advocating intervention in competitive markets with external economies of scale, by means of adopting self-financing tax subsidy schemes. The originality of the analysis consists of stressing that these policies can always be implemented in one or another way. Further examination of the issue is, however, needed to evaluate the practical relevance of this idea and to examine to what extent certain specific industries are characterised by external economies of scale.

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