Pareto-improving income redistribution: expanding consumer access to the vaccines market

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Abstract Economic theory has proved that income redistribution in imperfectly competitive markets can increase social welfare and lead to Pareto-improving situations. This paper shows that, under certain assumptions, self-financing tax subsidy schemes can have Pareto-improving effects also in a competitive framework. This result is achieved by exploiting external economies of scale, resulting in a decrease in price along with an increase in output. The case of the vaccines industry and World Health Organization initiatives are examined to illustrate the theoretical analysis.

Keywords External economies of scale · Income transfer redistribution · Pareto-improving tax-subsidies · Vaccines industry

JEL Classification D31 · D64 · H2 · L13

1 Introduction

This paper aims to analyze Pareto-improving income redistribution in the context of competitive markets with external economies of scale. Previous studies have shown that transferring resources between agents does not always hurt the donors. For instance, a government intervention through income transfers could correct the market failures associated with imperfect competition and restore Pareto efficiency. [Dillén \(1995\)](#) tackles the issue in a general equilibrium setting, and [Thépot \(2003\)](#) explores

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the case of a monopoly in which the implementation of a tax subsidy scheme results in welfare improvements to all agents involved.

In the [Thépot \(2003\)](#) paper, the transfer mechanism is used as a device to increase the price elasticity of demand, which yields lower prices in the monopoly case. Under certain assumptions, the price reduction compensates for the payment made by contributing consumers, thereby leading to Pareto-improving situations. However, even if his analysis goes beyond the monopoly case, it is always constrained to situations with some degree of market power. In any case, the results of the aforementioned papers are derived by correcting market failures arising in imperfect competition frameworks. Besides, Pareto-improving effects are not surprising when some degree of market power exists because regulations can easily bring forth greater efficiency by moving the equilibrium closer to a competitive situation.

The present paper deviates from the previous approach because we examine Pareto-improving income redistributions but in the context of competitive markets. Our analysis is developed for industries that exhibit external economies of scale, implying that the aggregate supply function presents a negative slope in the long run. Using the distinction between internal and external economies of scale introduced by Marshall ([1920](#), p. 221), we recognize external economies when a decline in unit costs arises from an industry expansion without a necessary increase in individual firm sizes. Of course, this is possible because additional firms may enter the market in the long run.

Government intervention can reduce the average production cost insofar as it is able to expand industry output, which then reduces the costs of the individual companies operating in the industry. Because of a lower average cost, industry expansion at equilibrium is then associated with a lower price. In this context, if the demand function becomes more elastic, the total amount exchanged in the industry may increase as the equilibrium price declines. Consequently, any policy that increases the elasticity of demand can potentially lead to Pareto-improving situations.¹

The alteration of the demand curve can be caused by the introduction of tax-subsidies schemes. For instance, [Garcia-del-Barrio \(2012\)](#) addresses tax-subsidy schemes, income redistribution, and government purchasing commitments in this context. Previously, [Glazer and Konrad \(1993\)](#) show that—under certain conditions—a transfer of income can be Pareto-improving and entail welfare gains to all individuals. However, our approach differs from theirs because our analysis is based on external economies of scale rather than on externalities such as congestion.² Moreover, the

¹ The fact that tax-subsidies may remedy externalities in competitive markets was stressed in previous papers. First, [Aoki \(1971\)](#) shows that the presence of externalities in different economic environments induces efficiency in the market mechanism through a tax-subsidy system. Furthermore, [Osana \(1977\)](#) proves how, in a various types of economies with Marshallian externalities, a tax subsidy system in a competitive context may be consistent with a Pareto optimum. More recently, [Geanakoplos and Polemarchakis \(2008\)](#) argue that a competitive equilibrium could be Pareto improved by adopting a set of taxes involving competitive reallocations: the presence of externalities makes private and social costs differ, thereby implying that competitive equilibria are unlikely to be Pareto efficient. The analysis of these papers differs from the scope of our study.

² In the aforementioned paper, [Garcia-del-Barrio \(2012\)](#) examines the Pareto-improving effects of applying tax-subsidy schemes associated with *ex ante* purchasing commitments by countries. However, the theoretical proposal of that paper seems difficult to implement in practice. In another study, although far from our

originality of the analysis developed in this paper is that it permits the conclusion that self-financing tax subsidy policies can be implemented in a manner that allows them to yield Pareto-improving outcomes.

From a theoretical perspective, economists typically acknowledge that external economies of scale are compatible with competitive markets. Chipman (1965, pp. 736–749) offers a general discussion on this issue and Chipman (1970) describes the theoretical debate and explains the differences between internal and external economies of scale in a general equilibrium model with perfect competition. Then, Meade (1952, p. 33) makes clear that perfect competition can prevail under conditions of increasing returns insofar as the economies are external to individual firms. Additionally, some previous studies collect examples of industries with external economies of scale. This feature is commonplace in various types of manufacturing industries but also affects prominent cultural goods markets, including the movie industry.³ In this context, our theoretical approach provides a rationale for the existence of certain types of economic policies, such as granting computers to children in India or low-cost access to mobile phone technology in African countries.⁴

The aim of this paper is to show how tax subsidy schemes can be implemented to enable them to lead to an equilibrium in which all agents enjoy a better welfare situation. To ensure that the redistributive transfer only affects the demand function of the specific industry under examination (rather than the demand elasticities in other markets), we assume that the tax applies to consumption and the subsidy is granted in the form of a voucher.⁵ Our study ultimately advocates that regulation of competitive markets may be profitable in the presence of external economies of scale. In the context of external economies, this paper proposes two different model settings to prove that

Footnote 2 continued

approach, Romano (1991) addresses diversity in consumption and excessive spending in goods (beyond their demand) as a rational decision of consumers who want to protect their surplus.

³ Broadberry and Marrison (2002) report strong evidence of the presence of external economies of scale in the cotton industry. Based on available data on trade, Marvasti (1994) stresses how highly populated countries dominate the exportation of most cultural products, such as books, motion pictures, recorded music, newspapers, and others. The latter paper argues that the comparative advantage of these countries basically stems from economies of scale granted by population size. Stropfer (1989) recognizes the existence of external economies of scale in the film industry that stem from the development of the social division of labor. The study of economies of scale for the vaccines industry is addressed by Scherer (2007); however, note that the types of economies he mentions are internal to firms.

⁴ Some theoretical elements of our paper may be helpful to understand existing initiatives. For instance, the One Laptop per Child program, headed by Nicholas Negroponte of MIT's Media Lab, provides low-cost laptops to children in developing countries. The target price of 100 dollars per laptop requires a minimum order of one million units per country to enable the producers taking advantage of economies of scale. Similarly, the startup Datawind, run by Suneet Tuli, is planning to provide every schoolchild in India with the world's cheapest functional tablet computer.

⁵ The scope and applicability of our analysis is possibly broader if considering highly esteemed goods or when dealing with goods consumed at a rate of one-unit per period, such as certain medicines or education. In any case, the analysis is soundly valid if a tax is assigned on consumption and the subsidy is granted conditioned on purchasing a specific type of good (and no other goods). Following Thépot (2003), consumers' reservation prices for one unit-good stem directly from personal income: that is to say, in our case, parameter s stands for the income of the richest consumer.

redistributive income policies can always be designed in competitive industries to lead to Pareto-improving situations.

This paper is organized as follows. Having reviewed the literature in the introduction, Sect. 2 develops two alternative model settings. First, Sect. 2.1 examines the case of a linear transfer redistribution similar to the one in Thépot (2003), but that is tailored to account for a competitive framework. Second, Sect. 2.2 describes and analyzes a more plausible implementation of the income redistribution policy. The implications of our results are reported in Sects. 3 and 4 proposes the vaccinations industry as an example to illustrate that the theoretical analysis is relevant to examine existing industries. Finally, Sect. 5 summarizes the main conclusions.

2 Two alternative settings of the model

The study of Pareto-improving income redistributions in a competitive framework can be addressed for many functional specifications, as illustrated in Fig. 1. The initial industry demand is denoted by $D_1(Q)$ and is depicted in the figure through the points: $si E_1gh1$. The long-run aggregate supply is the function across point $2\sqrt{aF}$ and passes through E_1 and E_2 . Equilibrium is initially found at (P_1, Q_1) , where P denotes the price and Q accounts for the aggregate quantity exchanged in the industry. In this figure, as is subsequently explained in this paper, F corresponds to the fixed set-up cost and parameter a is the quadratic form of the variable cost. Additionally, t denotes the tax rate.

The basic idea of this paper is that changes in the demand function, caused by an income transfer, imply that the total quantity increases and the price decreases, which potentially draws the approval of all economic agents.

Consider the case of an income redistributive policy that transforms the initial demand $D_1(Q)$ into $D_2(Q)$, where the latter function is represented in Fig. 1 by

Fig. 1 Pareto-improving income redistribution with external economies. Changes in the demand function may increase the total quantity while reducing the price, implying that all the agents benefit from welfare improvements

the reunion of points: riE_2h1 . Of course, this change induces an alteration of social welfare. In a competitive industry, the “extraordinary” profits must be equal to zero, such that total welfare coincides with consumer surplus. The consumer surplus for $D_1(Q)$ is given by the area $s\widehat{P_1E_1}$, whereas $r\widehat{P_2E_2}$ stands for the new demand $D_2(Q)$. Accordingly, the increasing-welfare function is defined as the difference between consumer surplus after and before a change in demand:

$$W = \int_0^{Q_2} D_2(Q)dQ - P_2Q_2 - \int_0^{Q_1} D_1(Q)dQ + P_1Q_1 \quad (1)$$

Expression (1) evaluates the increase in welfare derived from the implementation of the income redistributive policy. Any desirable social policy must yield increases in welfare, thereby requiring (1) to be positive. Furthermore, for a policy to be Pareto-improving, it must fulfill the following more demanding requirement:

- *Condition 1:* A Pareto-improving transfer requires that the final welfare level of each and every consumer should be at least as high as the welfare they had before the income transfer; i.e.,

$$P_1 - P_2 \geq t \quad (2)$$

Note that whenever inequality (2) is satisfied, the increase in social welfare is immediately guaranteed; however, the relationship in the opposite direction does not hold.

Our aim is to illustrate the theoretical possibility of implementing policies leading to Pareto-improving situations. For the sake of clarity, the two models presented thereafter are settled for linear specifications of demand and supply. Of course, although our basic conclusions are generally valid, further analysis might be advisable to examine the results in a more general setting.

First, we consider a market with a continuum of consumers. The individuals’ preferences are assumed to be identical, whereas their disposable incomes (to buy this good) differ. To simplify the calculations, the total quantity demanded in the industry at zero price is normalized to 1. Then, assuming that the population is uniformly distributed, the aggregate demand $D_1(Q)$ is of the form: $P = s - sQ$. Note that both linearity and normalization of the demand function are made for the sake of simplicity and do not entail loss of generality.

Second, we assume the total cost function, $TC(x, Q) = F + ax^2 - bxQ$, where x is production of the individual firm and F stands for the fixed set-up cost. In this expression, the degree of external economies of scale is driven by b , whereas a is the parameter of the quadratic form of the variable cost.

Note that, to simplify the calculations, we may consider a specification of the total cost function such that the external economies of scale do not alter the optimal level of production of the individual firms: $x = \sqrt{F/a}$. Alternatively, the following form of the total cost function can also be defined with no alteration whatsoever of the conclusions or the theoretical analysis:

$$TC(x, Q) = (2\sqrt{aF} - bQ)x$$

Under the latter cost structure, firms exhibit constant returns to scale, even if the average cost associated with technology (which is constant for each firm) varies along with the market size. In this context, there is not a single optimal production level, and firms may be of different sizes. With this type of function, the minimum average cost is defined for all firms in the industry as $2\sqrt{aF} - bQ$, regardless of the individual amount produced by the firm.

Note that identical results are achieved with either of the two alternative cost functions. In other words, the fact that firms produce the same or different individual amounts of a good (before and after the externality) is absolutely irrelevant to the analysis and conclusions of our paper. Actually, both cost structures lead to the same aggregate supply, which in our model is a linear function with a negative slope in the long run: $P = 2\sqrt{aF} - bQ$. This is because the price must equal the minimum average cost given that firms accrue zero “extraordinary” profits in long-run perfect competition equilibria.

Additionally, to ensure the existence of industry equilibrium for positive values of price and quantity, the following conditions on the parameters are imposed:

$$b < 2\sqrt{aF} < s \quad (3)$$

2.1 The case of a linear transfer redistribution

In this framework, income redistribution can be viewed as a mechanism for increasing the price elasticity of demand. Following [Thépot \(2003\)](#), consider the case of a linear redistribution implemented through a self-financing tax subsidy scheme. The transfer redistribution is designed to split the population into three groups: (1) the donors; (2) the recipients; and (3) the excluded consumers. In this framework, the policy can be designed to maximize the increase in welfare or, alternatively, to minimize the number of excluded individuals.

For the normalized aggregate demand $D_1(Q)$, the maximum consumption level is achieved at $Q = 1$. (Note that D denotes the price as a function of Q). Then, a linear redistributive transfer distorts the effective demand curve, for the Q_2 consumers affected, implying that it becomes $D_2(Q)$.

Let us consider a linear transfer implemented in the form of a negative income tax scheme. Thus, the redistributive transfer is defined as:

$$T(Q) = \begin{cases} D_2(Q) - D_1(Q) & \text{for } 0 < Q < Q_2 \\ 0 & \text{for } Q_2 < Q < 1 \end{cases} \quad (4)$$

By imposing a self-financing transfer characterized by an identical tax and subsidy rate t , half the Q_2 consumers⁶ receive a subsidy (of t times their personal income),

⁶ Note that it is precisely the linear setting to provoke the division of the Q_2 into two groups of an identical number of consumers. For Fig. 1 to illustrate this point, consider that all curves in that figure are linear functions, which automatically implies $Q_i = Q_2/2$.

whereas the other half pays a tax of a similar proportional amount. The remaining consumers $(1 - Q_2)$ experience no change in their income or in their willingness to pay. The condition for the transfer to be self-financing is then:

- *Condition II*: A self-financing income transfer redistribution requires that the total tax payment must equal the total subsidy; i.e.,

$$\int_0^{Q_i} (D_1(Q) - D_2(Q)) dQ = \int_{Q_i}^{Q_2} (D_2(Q) - D_1(Q)) dQ \quad (5)$$

This condition permits specifying the particular form of the new demand, $D(Q)$. In the linear setting, as generally illustrated by Fig. 1, the intercept of (Q) is found at $r = s - t$. To calculate the new slope, denoted as β , we solve $\int_0^{Q_2} ((s - t - \beta Q) - (s - sQ)) dQ = 0$ and express the result in terms of β . Once the self-financing transfer is fully implemented, the demand function is defined by two elements:

$$D(Q) = \begin{cases} s - t - sQ - \frac{2tQ}{Q_2} & \text{for } 0 < Q < Q_2 \\ s - sQ & \text{for } Q_2 < Q < 1 \end{cases}$$

Let us now examine the conditions for the transfer to be Pareto-improving. In our model, the initial price P_1 is a fixed value determined by the parameters, whereas P_2 depends on t :

$$P_1 = \frac{s(2\sqrt{aF} - b)}{s - b} \quad \text{and} \quad P_2 = \frac{s(2\sqrt{aF} - b) - bt}{s - b}$$

Hence, in the context of the linear case, *Condition I*, defined in expression (2), becomes:

$$2b \geq s \quad (6)$$

In other words, for the income transfer to be Pareto-improving, it simply requires the fulfillment of the aforementioned relationship between the degree of external economies of scale, b , and the slope of the demand function, s . Moreover, if the slope of the demand is smaller than twice the size of the external economies of scale, thus satisfying condition (6), an increase in social welfare is automatically warranted. The last result can be easily proved by examining the increasing welfare function:

$$W(t) = \frac{t}{2(s - b)^2} \left((2b - s)t + 2b(s - 2\sqrt{aF}) \right) \quad (7)$$

If conditions (3) and (6) are fulfilled, then $W(t)$ is always positive. Consequently, for any positive value of t , social welfare will always improve.

Proposition 2.1 *In the linear case, the optimal linear transfer (to maximize the increase in welfare) is achieved at the level of the full-coverage tax rate.*

Proof $W(t)$ increases along with t , implying that its maximum value is achieved at the greatest feasible value of t . The fact that $W(t)$ is always an increasing function of t can be easily proved by computing its first derivative with respect to t :

$$W'(t) = \frac{\partial W(t)}{\partial t} = \frac{1}{(s-b)^2} \left((2b-s)t + b(s-2\sqrt{aF}) \right)$$

For parameter values satisfying (3) and (6), and for any $t > 0$, the previous expression is positive, meaning that the increase in welfare becomes larger as t increases.

Given that $Q \in (0, 1)$, because the demand function has been normalized to 1, to maximize total welfare we must choose the value of t associated with full-coverage: $Q_2 = 1$. Hence, the optimal solution (if feasible) for $2\sqrt{aF} > b \geq \frac{s}{2} > \sqrt{aF}$ is:

$$t^* = t_c = 2\sqrt{aF} - b \quad (8)$$

where t^* denotes the tax-subsidy rate that maximizes the increase in welfare, and t_c the rate corresponding to full-coverage. This result means that the best policy, in terms of welfare, consists of procuring a perfect full-coverage, which demonstrates the validity of Proposition 2.1.

In conclusion, for a linear transfer redistribution, the success of the policy to increase social welfare crucially depends on the relative magnitude of the external economies of scale with respect to the elasticity of demand. In particular, the applicability of a Pareto-improving policy is only warranted if the slope of the aggregate demand is smaller than twice the slope of the long-run supply in the industry. The best policy in this context is applying a linear transfer, which leads to full-coverage of the market.

This initial approach has helped to show that Pareto-improving policies could always be implemented when external economies of scale exist in the industry. However, the result depends on condition (6). More importantly, linear transfer redistributions are difficult to implement in practice. These two reasons encourage us to develop the more plausible framework of Sect. 2.2. $\square$

2.2 A self-financing transfer in two steps

The following analysis aims to develop a framework in which income transfer could be implemented in a more realistic manner. Assuming the existence of external economies of scale in the industry, we propose implementing a self-financing income transfer in two steps.

In a market with these characteristics, the starting equilibrium indicates the number of individuals who can initially afford the good and the price they pay:

$$(Q_1, P_1) = \left(\frac{s-2\sqrt{aF}}{s-b}, \frac{2\sqrt{aF}-b}{s-b}s \right)$$

We presume that the government is able to accurately evaluate the existing external economies of scale. The differences with respect to Sect. 2.1 are the result of the

different nature of the tax subsidy scheme as well as the timing of its implementation. Additionally, the tax now consists of a fixed identical amount paid by each of the Q_1 contributing consumers, whereas the subsidy is assumed to be proportional to the lack of disposable income of subsidized consumers. We also assume that the tax collecting process takes place in an early stage, when the first wave of consumers purchase the good, whereas the provision for the subsidy occurs only afterwards. These features are described in Fig. 2, where the supply and demand curves are represented as linear functions, in line with our simplified analysis.

Had the government not intervened in the industry, Q_1 would be the total quantity exchanged at price P_1 . Nonetheless, the provision of subsidies to individuals beyond Q_1 permits a second wave of transactions in the market. The process is described in two subsequent steps:

1. The first group of individuals (all those whose willingness to pay exceed the initial price) pays P_1 , which is the only way to ensure that the good is available. Otherwise, if waiting for the second round, individuals face the certain risk that the commodity will run out. In other words, for highly esteemed goods, consumers who can afford P_1 , located between 0 and Q_1 , will certainly be willing to pay the

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initial price. (Part of this payment will then be kept by the government as a tax with which to subsidize new consumers).

2. In the second stage, consumers between Q_1 and Q_2 receive individual subsidies (of different amounts for each consumer depending on their willingness to pay) that allows them to afford the respective price. We propose here that the price charged to every additional unit declines along with the long-run supply function, starting at P_1 and ending at price P_2 (from E_1 to E_2).

This type of tax-subsidy scheme tailored in two stages prevents the possibility that consumers able to afford the initial price attempt to benefit from the subsidy. If the government provides no information on the actual quantity of the good available at the subsidized price, the fear of being excluded from the market stops any attempt to cheat on the part of the Q_1 initial consumers. The critical issue is providing the right incentives for people to disclose their real willingness to pay. For this aim we consider useful our proposal, including the uncertainty over the number of units produced and still available.⁸

Moreover, we might assume that the government adopts an advanced commitment to purchase the excess quantity. The agreement could be made for producers to provide additional amounts at prices indicated by the shape of long-run supply function. Therefore, the government intervention expands the size of the market from Q_1 to Q_2 , which reduces the cost per unit from P_1 to P_2 . Because the government has agreed to pay prices higher than P_2 , the policy conveys positive “extraordinary” profits for producers and permits additional consumers to gain access to this market.

Of course, we assume that the usual relationship between the willingness to pay and Q , which holds in any demand function, also applies here. Accordingly, the actual demand function may be described as:

$$D(Q) = \begin{cases} s - sQ & \text{for } 0 < Q < Q_1 \text{ and } Q_2 < Q < 1 \\ 2\sqrt{aF} - bQ & \text{for } Q_1 < Q < Q_2 \end{cases}$$

Alternatively, the function describing the overall amount that society demands is:⁹

$$Q(D) = \begin{cases} \frac{s-D}{s} & \text{for } P_1 < D < s \text{ and } h' < D < 1 \\ \frac{1}{b}(2\sqrt{aF} - D) & \text{for } 0 < D < h' \end{cases}$$

After adopting the tax-subsidy transfer, the competitive equilibrium price in the industry is P_2 , implying that initial buyers are also contributing consumers because

⁸ Further research might address this issue by adopting the Vickrey-Clarke-Groves auction system. In this type of auction, bidders reveal their valuations for the items and ignore other contestants' bids. With respect to our aim, the important aspect of this type of auction procedure is that it introduces the right incentives for them to reveal true valuations, by ensuring that bidding on the true value of the items is the optimal strategy for each participant. This type of auction system is named after [Vickrey \(1961\)](#), [Clarke \(1971\)](#), and [Groves \(1973\)](#) for their papers on the idea of a sealed-bid auction for multiple items.

⁹ Note that the second segment of this peculiar social demand function involves the willingness to pay of private consumers and that of the government, which is granted as a complementary payment to individual consumers.

they paid P_1 . This account of the facts implies that the producers keep the area $\widehat{k'ki}P_2$ as profits. Alternatively, instead of paying P_1 , the transfer could have been designed for the Q_1 initial consumers to spend a smaller amount $P_2 + t$, implying that the surplus benefits consumers rather than producers. Regardless of whether we assume the former or the latter, the government collects the total tax $\widehat{sE_1kr}$ with which to afford the subsidies given to the second wave of new consumers.

To achieve greater efficiency at assigning the good to the second group of consumers, the subsidies might be granted through an auction process in which each consumer pays a different price. The first consumer is willing to pay P_1 ; however, every additional consumer within Q_1 and Q_2 —because of ignorance of the spare amount of commodity still available—bets for the good by offering the price indicated by the original demand: $D(Q) = s - sQ$. Then, the government subsidizes the difference to reach the aggregate supply. The process finishes at Q_2 , where the total tax payment equals the total subsidy.

Let us now analyze the effects of this income transfer program. Again, the initial assumptions for the slope and intercepts of condition (3) must be fulfilled. Additionally, condition (5) must hold for the transfer redistribution to be self-financing, which in the linear case implies:

$$tQ_1 = \int_{Q_1}^{Q_2} (2\sqrt{aF} - bQ - (s - sQ)) dQ \quad (9)$$

In the present framework, condition (9) leads to establishing a relationship between the tax and the number of units eventually sold, Q_2 . In other words, the following functional relationship is defined to ensure that the transfer program is self-financing:

$$Q_2(t) = \frac{s - 2\sqrt{aF} + \sqrt{2t}\sqrt{s - 2\sqrt{aF}}}{s - b} \quad (10)$$

However, because the price change can also be expressed as a function of t , the previous condition can be transformed into:

$$t \leq \frac{s - 2\sqrt{aF}}{(s - b)^2} 2b^2 \quad (11)$$

Because of this transfer program, as Fig. 2 illustrates, the increase in social welfare is given by the sum of areas $\widehat{k'ki}P_2$ and $\widehat{E_1iE_2}$. Then, the increasing-welfare function is defined by:

$$W(t) = \frac{s - 2\sqrt{aF}}{(s - b)^2} \left((2b - s)t + b\sqrt{2t}\sqrt{s - 2\sqrt{aF}} \right) \quad (12)$$

This expression is useful to determine the optimal tax rate t^* and to examine the extent to which other relevant values of t entail welfare improvements.

In particular, it is worth examining the values of t , defined in terms of the parameters that are especially significant: (I) the tax rate t_c at which society reaches full-coverage; (II) the tax t_p for which the decline in prices is exactly identical to the chosen tax rate; and, (III) the optimal tax t^* that procures the maximum increase in social welfare. We subsequently discuss the conditions under which they can actually be implemented.

- (I) *Tax t_c of full-coverage* To ensure that the entire population eventually enjoys the good, the government should apply the tax value associated with full-coverage. Accordingly, t_c is obtained by substitution of $Q_2 = 1$ in expression (10), which yields:

$$t_c = \frac{1}{2} \frac{(2\sqrt{aF} - b)^2}{s - 2\sqrt{aF}} \quad (13)$$

- (II) *Tax t_p to equalize the decline in price* The other conceivable policy is establishing the value of t that reduces the price by exactly the size of the tax. Hence, tax t_p is calculated as the value at which condition (11) holds as a strict equality, implying:

$$t_p = \frac{s - 2\sqrt{aF}}{(s - b)^2} 2b^2 \quad (14)$$

- (III) *Tax t^* to maximize the increase in welfare* We refer to optimal taxation as the tax rate associated with the greatest welfare. Note that, for $s \leq 2b$, function $W(t)$ always increases along with t . In this case, the maximum welfare level corresponds to a corner solution defined by the greatest feasible value of t . In contrast, if $s > 2b$, the optimal taxation is calculated as the critical value of expression (12), which leads to:

$$t^* = \frac{1}{2} \frac{s - 2\sqrt{aF}}{(s - 2b)^2} b^2 \quad (15)$$

This value is only congruent if it satisfies some conditions that will be subsequently discussed. Before we do that, let us prove that the critical value defines a maximum under the condition that $s > 2b$. The increasing-welfare function was defined in expression (12) as:

$$W(t) = \frac{s - 2\sqrt{aF}}{(s - b)^2} \left((2b - s)t + b\sqrt{2t}\sqrt{s - 2\sqrt{aF}} \right)$$

The first-order condition to determine the critical value is then given by:

$$W'(t) = \frac{\partial W(t)}{\partial t} = \frac{s - 2\sqrt{aF}}{(s - b)^2} \left((2b - s) + \frac{b\sqrt{2}}{2\sqrt{t}} \sqrt{s - 2\sqrt{aF}} \right) = 0$$

Fig. 3 Determination of different tax rates. Considering just the policies that are simultaneously affordable, feasible, and Pareto-improving, the figure illustrates the way in which each of the three tax rates is obtained. Under certain circumstances, and depending on the relative position among them, some tax rates may not be feasible

Solving this equation leads to expression (15). Nonetheless, this value corresponds to a maximum if and only if the second order condition holds. Therefore, we compute the second derivative of $W(t)$ with respect to t , which yields after substitution of t^* :

$$W''(t^*) = -\frac{1}{b^2} \frac{(s - 2b)^3}{(s - b)^2}$$

The tax rate t^* defines a maximum if and only if $W''(t^*)$ is negative, which obviously requires:

$$2b < s$$

Additional constraints must be fulfilled to actually implement each of the values of t , defined in (13), (14), and (15). These conditions may be expressed in terms of the parameters. The discussion of this feature is crucial to determine the outcome of the transfer programs and the circumstances under which each of them should be implemented.

In Fig. 3, we illustrate how each of the three tax rates are obtained and clarify that some tax rates may not be feasible in certain circumstances depending on the relative positions among them.

Our approach limits us to consider the policies that are affordable, feasible, and Pareto-improving at the same time. The first point (that society can afford the policy) is—by construction—guaranteed because our framework only considers self-financing transfers; however, the two other characteristics require further examination.

First, for the policy to be relevant, t must lie within the feasible region. In our model, $Q \in (0, 1)$; that is to say, given the normalization imposed on the demand function, the quantity associated with any tax level must be smaller or equal to unity. Equivalently, for the policy to be potentially applicable, the size of the tax cannot be greater than expression (13), which may be considered a feasibility constraint.¹⁰

In addition, the choice of the tax level requires paying attention to the specific target that the government pursues. Hence, our analysis is arranged to suit the two most relevant conceivable policies: to maximize the degree of coverage in the industry and to maximize the total increase in welfare.

2.2.1 The government seeks to maximize market coverage

The goal of granting industry access to as many consumers as possible means that the government faces a twofold choice between values (13) and (14). The total quantity transacted in the industry is an increasing function of t , implying that the maximum coverage level is precisely achieved at the greatest value of t (obeying, of course, the constraints).

The solution to this problem is straightforward because only the smallest of these two values is actually relevant. This is because tax rate (14) is not feasible for t_c smaller than t_p , whereas (13) infringes the Pareto-improving condition if the opposite holds.

Consequently, t_p must be adopted in the case that:

$$2\sqrt{aF} \geq \frac{b(3s-b)}{s+b} \quad (16)$$

Accordingly, the level of coverage and the resulting increase in the welfare function for level t_p are given respectively by:

$$Q_2(t_p) = \frac{(s - 2\sqrt{aF})(s+b)}{(s-b)^2} \quad \text{and} \quad W(t_p) = \frac{(s - 2\sqrt{aF})^2}{(s-b)^4} 2b^3$$

In contrast, if inequality (16) is not satisfied and the opposite relationship holds, the tax level must be established at the value reported in expression (14). Note that the government succeeds anyway in its purpose of maximizing coverage. Moreover, if the tax rate is settled at t_c , the maximum coverage leads to the perfect full-coverage of the market. Obviously, in the latter case, the quantity exchanged takes the value of 1, and the increase in welfare is determined by the value of $W(t_c)$:

$$Q_2(t_c) = 1 \quad \text{and} \quad W(t_c) = \frac{s - 2\sqrt{aF}}{(s-b)^2} \left(2b(s-b) - s(\sqrt{aF} - b) \right)$$

¹⁰ The three values of t that we have defined (t_p , t_c , and t^*) are relevant depending on whether or not certain conditions hold. Given that the corresponding restrictions take the form of inequalities, the issue could be addressed by applying Kuhn-Tucker techniques. Nonetheless, we adopt instead a descriptive approach that is equally valid, leading to identical conclusions, but is more informative.

Note that, regardless of the size of the transfer, Q_2 is always greater than Q_1 , which is coherent with the model's design. Additionally, regardless of the tax rate (either t_p or t_c) actually adopted, social welfare will increase after the implementation of the transfer. This result is inferred from a simple inspection of $W(t_c)$ and $W(t_p)$: both are positive for parameters abiding by condition (3).

2.2.2 The government aims to maximize welfare

Consider instead that the intervention is designed to deliver the greatest possible increase in total social welfare. The value t^* is then calculated as the critical value of equation (12), which is reported in expression (15) and defines a maximum if and only if the second-order condition is verified:

$$2b < s \quad (17)$$

However, when this inequality is not fulfilled, $W(t)$ is always an increasing function of t . In this case, the maximum increase in welfare is found at a corner solution associated with a feasible tax rate (the smallest value between t_c and t_p). Nonetheless, even if condition (17) holds true, it does not necessary mean that t^* corresponds to the value that maximizes welfare. This is because t^* is unattainable unless two other additional conditions are simultaneously fulfilled.

First, for the optimal tax level to be feasible, it must be smaller than the value given in expression (13). Note that imposing $t^* < t_c$ is actually equivalent to $Q_2(t^*) < 1$, which is enforced through construction of the model. However, according to the underlying parameters of our model, the last condition requires:

$$2b < 2\sqrt{aF} \quad (18)$$

Besides, for the policy to be Pareto-improving, the chosen tax must be smaller than expression (14), i.e., $t^* < t_p$. Accordingly, and provided that condition (17) holds, the Pareto-improving requirement requires that:

$$3b < s \quad (19)$$

However, this inequality implies that expression (17) can be disregarded because it is always fulfilled under tighter condition (19). Hence, the value t^* of expression (15) must only be chosen if conditions (18) and (19) are simultaneously satisfied. Then, the level of coverage and the increase in welfare are obtained, respectively, by substitution of t^* in expressions (10) and (12). Both take positive values for any s strictly greater than $2b$:

$$Q_2(t^*) = \frac{s - 2\sqrt{aF}}{s - 2b} \quad \text{and} \quad W(t^*) = \frac{1}{2} \frac{(s - 2\sqrt{aF})^2}{(s - b)^2(s - 2b)} b^2$$

In the other cases, whenever one of conditions (18) or (19) fails, the optimal taxation level to maximize welfare is determined by the smaller of the two values defined in

either (13) or (14). Next, we carry out some additional analyses and comments to help understand the implications of our results.

3 Implications and policy recommendations

We are now ready to consider some policy recommendations derived from our analysis. This paper proved that Pareto-improving policies can be implemented through government interventions if one condition between the extent of external economies of scale and the slope of the demand function is fulfilled. To illustrate the discussion, Fig. 4 summarizes the findings.

On the one hand, the function resulting from expression (16) determines the cases in which t_c or t_p must be prescribed. Note that, in Fig. 4, the function changes position depending on the value of $2\sqrt{aF}$. To maximize coverage, t_c must be adopted whenever $t_c < t_p$, given that t_p is not feasible. Instead, if the opposite inequality holds, t_p must then be chosen because t_c infringes the Pareto-improving condition.

On the other hand, the necessary conditions (18) and (19) delimit the area shadowed in Fig. 4, where value t^* can be implemented to maximize welfare rather than coverage.

The examination of the relationship among the different parameters teaches us important lessons that explain why the present paper outperforms Garcia-del-Barrio (2012) in terms of scope and far-reaching conclusions. For instance, the larger the s (intercept and slope of the aggregate demand) with respect to the other parameters, the greater the chances of reaching full-coverage in the market. We also learn that

Fig. 4 Maximizing coverage or welfare increase. The relationship among the parameters permits identifying whether t_c or t_p should be prescribed. In the figure, some functions change position depending on the value of $2\sqrt{aF}$. To maximize coverage, t_c must be adopted whenever $t_c < t_p$, given that t_p is not feasible. In the other cases, t_p must be chosen given that t_c infringes the Pareto-improving condition. The necessary conditions delimit the area, shadowed in the figure, where value t^* can be implemented to maximize welfare rather than coverage

parameters a and F always operate together, meaning that what matters is the intercept of the aggregate supply (which includes the fixed set-up cost as well as the quadratic element of the variable cost). In fact, a higher $2\sqrt{aF}$ indicates greater difficulty in reaching full-coverage. This is not surprising because higher costs imply a smaller margin and fewer resources to subsidize additional consumers.

Another implication of the model is that the preferred tax rate is frequently the same regardless of whether the government wishes to maximize coverage or welfare. This is the result of the fact that the best outcome is often the corner solution anyway. Only when b is sufficiently small relative to the other parameters does the aim of maximizing welfare (associated in this case with an interior solution) deviate from the tax level associated with maximizing coverage.

The main result of the paper is summarized in the following proposition:¹¹

Proposition 3.1 *In competitive industries with economies of scale, it is always possible to implement self-financing tax subsidy programs that lead to Pareto-improving situations. In these cases, additional consumers gain access to the market.*

Proof In our model, either t_p is feasible or t_c is Pareto-improving. Then, positive tax t values imply always greater levels of coverage and welfare. The increase in coverage is ensured by the fact that both $Q_2(t_c)$ and $Q_2(t_p)$ are each greater than Q_1 .

$$Q_2(t_p) = \frac{s+b}{s-b} Q_1 \quad \text{and} \quad Q_2(t_c) = \frac{s-b}{s-\sqrt{aF}} Q_1$$

This can be easily noticed because, for parameter values satisfying condition (3), each of the previous ratios multiplying Q_1 (both $\frac{s+b}{s-b}$ and $\frac{s-b}{s-\sqrt{aF}}$) are greater than 1. Similarly, without a doubt, welfare will increase once the transfer has been implemented. The value of $W(t_p)$ is always positive, whereas $W(t_c)$ is positive for the only relevant case in which t_c is chosen, which occurs when expression (16) does not hold. However, if this is the case, then: $2b(s-b) - s(2\sqrt{aF} - b) > b2\sqrt{aF}$. Hence, the increase in welfare $W(t_c)$ is, by definition of the underlying parameters, greater than a positive value:

$$W(t_c) > \frac{s-2\sqrt{aF}}{(s-b)^2} b2\sqrt{aF}$$

Finally, even if our results are derived in a linear framework, a simple glance at Fig. 2 reveals that they are valid for broader (non-linear) settings. $\square$

4 An illustrative example: the vaccines industry

To illustrate the relevance of our theoretical analysis, this section examines the vaccines industry and, more particularly, the provision of vaccines for preventing influenza A

¹¹ This proposition must be interpreted in the context of our model and subject to respecting the assumptions. For instance, we assume that either the good is indispensable for consumers or the subsidy is granted in kind (or in the form of a voucher exchangeable only for this particular good).

(H1N1) from spreading in 2009 and 2010. Firstly, two points need examination: the existence of external economies of scale in the vaccines industry and a discussion of market structure.

Regarding the former issue, several papers may be invoked. The study of the U.S. vaccines market by [Danzon et al. \(2005\)](#) implicitly acknowledges their existence when expressing that vaccines should be marketed globally to exploit scale economies. Some quotes may help to understand their view, even if their paper does not clarify whether internal or external economies of scale should be recognized: “production [of vaccines] is characterized by very high fixed, sunk cost and low marginal cost per unit within each batch (...). This structure of high fixed costs and low marginal costs, which reflects both the regulatory requirements and the technology of vaccine production (...), including many that are country-specific, plausibly contribute to the reluctance of some foreign manufacturers to launch some of their vaccines in the United States. (...) High fixed costs of regulation and production are not barriers to entry if these costs can, with reasonable certainty, be recouped over large volume...” (p. 710). Also: “High fixed costs would be spread most widely if each vaccine were distributed globally. (...) Country-specific requirements limit the potential for manufacturing economies of scale and may require the development of country-specific products” (pp. 711–712).¹²

These arguments, which go beyond our current discussion, are good explanations for why few companies settle down in regulated markets such as the United States. However, companies simultaneously recognize the relevance of economies of scale and the possibility that other market situations take place in the absence of tight regulations.¹³ More appropriate to match the goal and scope of our paper is possibly the contribution by [Gordon et al. \(2008\)](#), who acknowledge the existence of external economies of scale at the research and development stage of vaccines. (A description of this and other aspects are broadly detailed in the “Appendix”).

Indeed, the large potential size of the market (1 billion doses of vaccinations were initially agreed on between the governments of the major economies and the industry only in 2009) may have permitted a reduction in the average cost per influenza vaccine to approximately 2.50 Euros. On the basis of this evidence, the cost of developing vaccines seems to decrease along with market size: the more units produced, the cheaper the average costs. The number and size of the firms is actually irrelevant in

¹² Regarding research activities in the pharmaceutical industry, [Acemoglu and Linn \(2004\)](#) study the relationship between innovation and potential market size and conclude that too little research is typically carried out in small markets, especially if these markets have little ability to pay. Also [Kremer \(2002\)](#) stresses that pharmaceutical research is driven by market size. Precisely on the basis of this premise, he claims that government incentives are needed to develop medicines against diseases in less developed countries. For the pharmaceutical market in India, [Mazumdar \(2013\)](#) mentions the existence of scale economies for the overall pharmaceutical industry and for all groups of firms. In this country, the top 25 companies capture approximately 85% of the market, and the rest of the market is dominated by approximately 250 small firms).

¹³ Additionally, [Scherer \(2007\)](#) acknowledges the existence of economies of scale. However, his paper seems completely focused on internal economies of scale despite invoking the role of externalities in asking the government to subsidize some vaccine producers. Regarding the pharmaceutical industry as a whole, [Matraves \(1999\)](#) explains how reaching new geographical markets brings forth incentives to escalate R&D to capture a larger market share: “The continuing globalisation process increases effective market size as leading firms have access to new geographical markets”(pp. 190–191).

this regard, as was clarified in Sect. 2 through the proposition of two different cost structures.

The second critical aspect is the debate on market structure. Should the vaccines industry be considered an oligopoly or can it be treated as a competitive industry in the long run? In some domestic markets, such as the United States, in which few companies compete and numerous regulations exist, there seems to be little doubt that we are far from perfect competition.¹⁴ Nevertheless, the issue is different in larger markets, or when considering lower levels of analysis, such as the research and development activities carried out to produce new vaccines. In this regard, Cockburn (2004) examines the structure of the pharmaceutical industry and concludes that distinguishing between activity levels is by no means meaningless in this regard. The paper focuses on the trade-off between specialization and vertical integration. The new vertical structure developed in the industry implies that “Big Pharma now increasingly relies on the research tools and product leads provided by biotechs, and 25–40 originated in the biotech sector” (p. 16).

Regarding the finding of appropriate examples, there are sound arguments in support of certain markets. Consider first that some circumstances may make legitimate the consideration of the vaccines market in a more aggregate context. This is likely the case when the World Health Organization (WHO) coordinates extensive worldwide programs. By supporting a broad array of actions, the WHO initiative presumably enlarges the size of the market, which makes the empirical analysis of Sect. 4 (and the description in the “Appendix”) a suitable example for illustrating our theoretical conclusions. This is reinforced by observing that Table 1 includes now a more complete description of companies supplying vaccines to various markets: the WHO registered at least 40 different manufacturers of the influenza vaccine (as of May 13, 2009).

On the other hand, domestic markets exist that have a considerable number of vaccines suppliers and in which the role of developing country manufacturers is becoming critical to assuring global access to vaccines. In these countries, as Milstien and Kaddar (2010) stress, heterogeneous producers supply more than 60% of traditional vaccine doses worldwide. The Indian vaccine market is perhaps the most relevant and deserves greater attention. A report entitled “Vaccines Market Access in India—New Vaccine Uptake Drives Growth” reveals that the Indian government (through the so called “Universal Immunization Program”) procures vaccines at very low prices, mainly from local manufacturers.¹⁵ The study further describes the existence of a large private market dominated by multinational companies, which is expanding as a result of the increasing economic capacity of the middle-class population.

¹⁴ Several papers examine the U.S. vaccines market (see Danzon and Pereira 2005; Danzon et al. 2005, or Danzon and Pereira 2011, for instance) conclude that high fixed sunk costs and relatively concentrated demand imply that only one or a few producers will remain in the long run.

¹⁵ The source is (www.researchandmarkets.com/research/g8n9m9/vaccines_market_ac), a report delivered by “Research and Markets.” It identifies four major multinational vaccine companies operating in India in 2012: GlaxoSmithKline; Merck Sharp & Dohme; Novartis; and Sanofi Pasteur. It also highlights the role played by six other domestic vaccine producers: Bharat Biotech; Biological E; Bio-Med; Indian Immunologicals; Panacea Biotec; and Serum Institute of India. According to this source, India is the largest manufacturer in the world (60% of global production), supplying vaccines to United Nations agencies and many countries.

Table 1 Influenza H1N1 - vaccine manufacturers: companies and donors

	Influenza vaccine manufacturers World Health Organization (13 May 2009)	Location	Product
1	Medimmune-Avirion	USA	FluMist
2	Baxter-Immuno AG	Austria/Czech Rep.	Influenza
3	CSL	Australia	Fluvax
4	GSK	Belgium	FluarixNH Fluarix SH
5	Butantan (Filler)	Brazil	Gripe Vaccine
6	Sanofi Pasteur	France	Mutagrip Vaxigrip Tetagrip
7	Sanofi Pasteur	USA	Fluozone
8	Novartis	Germany	Fluad
9	Novartis	Italy	Antigripal S1
10	Novartis	UK	Fluvirin Evagrip
11	Denka Seiken Co, Ltd	Japan	Influenza Seiken HA
12	Chemo-Sero-Therapeutic Research Institute	Japan	Influenza Kaketsuken HA
13	Kitasato Institute	Japan	Influenza HA
14	Biken	Japan	Influenza Biken
15	Dong Shin Pharmaceuticals (Filler)	Korea	Dong Shin Influenza HA
16	Korea Vaccine Co. Ltd (Filler)	Korea	Influ-kovax
17	Korea Green Cross (Filler)	Korea	Inflexal V
18	Solvay Healthcare	The Netherlands	Influvac
19	Cantacuzino Institute	Romania	Vaccin gripal trivalent
20	Immunopreparat Research association, Ufa	Russia	Influenza Vaccine
21	Products Immunologicals and Drugs. Irkustk	Russia	Influenza Vaccine
22	RIVS, Saint Petersburg	Russia	Influenza Vaccine
23	Berna-Crucell	Switzerland	InflexalV/Vitagrip/Fluviral
24	ID Biomedical	Canada	FluInsure
25	Wyeth Lederle	USA	Flushield
26	Torlak Institute	Serbia/Montenegro	Vaccinum Influenzae
27	Zhejiang Tianyuan-BioPharmaceutical Co. Ltd	China	Influenza
28	Sinovac Kexing Biological Product Co. Ltd	China	AnFlu TM
29	Beijing Institute of Biological Products (BIBP)	China	Influenza
30	Shanghai Institute of Biological Products (SIBP)	China	Influenza

Table 1 continued

	Influenza vaccine manufacturers World Health Organization (13 May 2009)	Location	Product
31	Changchun Institute Biological Products (CCIBP)	China	Influenza
32	Changchun Changsheng Life Sciences Ltd	China	Influenza
33	Lanzhou Institute of Biological Products (LIBP)	China	Influenza
34	Shenzhen-Sanofi Pasteur (Filler)	China	Influenza
35	Changzhou Yanshen Biotechnology Co.Ltd	China	Influenza
36	Liaoning Tiancheng Bio-pharmacy Inst. Co.Ltd	China	Influenza
37	Omninvest Ltd	Hungary	Influenza
38	Serum Institute of India Ltd	India	Home-grown vaccine
39	Panacea Biotech Ltd	India	Home-grown vaccine
40	Bharat Biotech International Ltd	India	Home-grown vaccine
Company	2009 Sales (Mill Euros)	Donors	Donations to WHO (Mill doses)
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		
Total	3300	Total	200

Sources: World Health Organization (WHO): List of influenza vaccine manufacturers posted by WHO in May 2009 (www.who.int/influenza/Influenza_vaccine_manufacturers2009_05), and: International meeting on the Influenza H1N1 Vaccine Market. “Asociación Mémoire des Luttés” (www.medelu.org) and KNOL unit of knowledge (<http://knol.google.com/k/influenza-2009-h1n1-vaccine-market>)

In the last paragraphs, we have addressed the vaccine market’s structure, which is actually linked to the number of firms in the industry. To properly address this matter, recalling some principles of economic theory is noteworthy. The field of industrial organization teaches that a sufficient number of firms makes an oligopolistic competitive environment similar to a perfectly competitive environment, as the following quote by Cabral (2000, p. 153) clarifies: “the performance of the Cournot model converges to perfect competition as the number of firms goes to infinity. (...) The model of perfect competition is a good approximation for markets in which there are many firms.”

Allocative efficiency is at its maximum under perfect competition. However, how many firms are needed for allocative inefficiency to be close to zero? The answer is also found in Cabral (2000, pp. 153–4), in which the estimations of allocative inefficiency are expressed, for comparison purposes, as a percentage with respect to the monopoly case. These calculations presume that oligopolistic firms behave according to the Cournot model, which is not a restrictive framework because Bertrand delivers outcomes closer to perfect competition. The implications of the results, computed for firms of identical size, are very enlightening because for just three firms, the allocative inefficiency of the Cournot equilibrium is only 25% of that of a monopoly. Moreover, this indicator shrinks to 16% for seven firms and to less than 1.6% (very near 0%) for 15 or more firms. Hence, the conclusion is clear. In Cabral's words, "It does not take a large number of identical firms for the performance of the Cournot model to be very close to that of perfect competition."

Regarding our examples, note that a significant number of companies (approximately 40 manufacturers, according to WHO records) were operating in the influenza vaccine industry in 2009, as shown in Table 1. Of course, other past situations have similar evidence, as Gordon et al. (2008) makes clear: "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 (pp. 40–41)." In any case, the important idea is that, even if not perfectly competitive, an oligopoly with many firms tends to be very close to the competitive framework. To provide an idea of the size of a number of domestic markets, Table 2 gathers some informative records.

A different matter is the fact that because laboratories must plan in advance the number of vaccines to meet demand, the implementation of self-financing programs requires prices and quantities to be agreed on up front. In particular, let us examine the WHO initiative against influenza H1N1. Some countries and a few companies donated a significant number of vaccines to less developed nations through the WHO. The data on potential donations are summarized in Table 3, whereas Table 4 reports the countries that benefited from the WHO influenza vaccine deployment initiative. (Further information on this initiative can be found in the "Appendix", which describes the nature and organization of the vaccines industry).

Governments are asked to commit themselves to purchase a certain number of vaccines at a price previously settled by the WHO depending on the standard of living of the country. This type of advanced government commitment has proved crucial for enabling new consumers to enter the vaccines market, which helps explain the industry's expansion. Note, however, that *ex ante* government purchasing commitments are invoked because they faithfully reflect real cases but also are for illustrative purposes. In other countries, health agencies directly negotiate (vaccine prices, among other terms) with companies, even if the vaccination programs are financed by the government,

Table 2 Pandemic influenza H1N1

Country	Price/unit (in Euros)	Ordered doses (Mill units)	Ordered market value (Mill Euros)	Purchased doses (Mill units)	Purchased market value (Mill Euros)
UK	8.70	132	1,148.4	48	417.6
USA	8.67	251	2,175.0	110	953.2
Spain	6.93	37	280.0	13	90.0
France	9.25			94	869.0
Germany	10.44			50	522.0
Netherlands	9.21			34	313.2
Italy	9.24			48	443.7
Belgium	8.75			13	110.2
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		

Vaccine orders (2009 and 2010)

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

which is what ultimately matters. In any event, it is worth noting that redistribution policies may be implemented through other mechanisms rather than tax-subsidy transfers. In other words, our proposal mainly relies on having financial support from the government, regardless of how income redistribution is actually implemented.

Indeed, advanced purchasing commitments may have helped enlarge the size of the industry. We advocate that increasing the potential size of the market was crucial for the minimum average production cost (of vaccines) to be reduced to only approximately 2.50 Euros per unit. Precisely, as [Danzon and Pereira \(2011\)](#) acknowledges, government purchases of vaccines tend to increase the amount and lower the price. [Acharyya and Garcia-Alonso \(2014\)](#) stress the relevance of government coordination at an international level to implement health policies through income redistribution and to examine the implications of price discrimination in this regard.¹⁶

¹⁶ In a previous paper related to improvements in medical innovation, [Acharyya and Garcia-Alonso \(2006\)](#) examine how income redistribution may help poor people gain access to health care and increase the utility of consumers who suffer from reductions in income. In a more complex approach to applying game theory, [Acharyya and Garcia-Alonso \(2012\)](#) explore other issues, such as market coverage and welfare.

Table 3 Evaluation of the potential vaccine donations

	Price/unit (in Euros)	Purchased doses (Mill. units)	Min. cost/unit (in Euros)	Max. cost/unit (in Euros)	Min. potential donations (Mill. Euros)	Max. potential donations (Mill. Euros)
Germany	10.44	50	2.50	4.72	285.8	397.0
Australia ^{a,c}	9.39	21	2.50	4.72	98.0	144.7
Switzerland ^{a,c}	9.37	13	2.50	4.72	60.4	89.3
South Korea ^a	9.37	13	2.50	4.72	60.4	89.3
Sweden ^a	9.34	18	2.50	4.72	83.2	123.2
Canada ^a	9.28	50	2.50	4.72	227.8	339.0
Hungary ^a	9.28	20	2.50	4.72	91.1	135.6
France ^c	9.25	94	2.50	4.72	425.5	634.5
Italy ^c	9.24	48	2.50	4.72	216.9	323.7
The Netherlands	9.21	34	2.50	4.72	152.6	228.2
Japan ^a	9.19	53	2.50	4.72	236.8	354.7
Greece ^a	9.18	24	2.50	4.72	107.0	160.4
Portugal ^a	9.11	28	2.50	4.72	122.9	185.2
Belgium	8.75	13	2.50	4.72	50.6	78.7
UK ^c	8.70	48	2.50	4.72	190.8	297.6
USA ^c	8.66	110	2.50	4.72	433.6	677.6
Spain	6.93	13	2.50	4.72	28.6	57.5
China ^a	5.80	65	2.50	4.72	69.9	214.5
Brazil ^c	4.72	10	2.50	4.72	0.0	22.2
Total donors	6.37 ^b	344	2.50	4.72	564.8	1329.6
Total	8.78 ^b	725	2.50	4.72	2941.9	4553.0

^a Data corresponding to ordered doses (instead of purchased)^b Average Prices (weighted by the amount of doses)^c Donor Countries: USA, UK, Australia, Brazil, France, Italy, Switzerland. (And also New Zealand and Norway, for which we did not found data)Sources: International meeting on the Influenza H1N1 Vaccine Market: "Asociación Mémoire des Luites" (www.medeu.org) and KNOL unit of knowledge (<http://knol.google.com/k/influenza-2009-h1n1-vaccine-market>). Report of the World Health Organization - influenza A (H1N1) vaccine deployment initiative (WHO web site: www.who.int)

The sale of large numbers of vaccines sold at low prices in poor countries was only possible after having succeeded in expanding the size of the market, which hence enables producers to reduce the unit cost per vaccine. Of course, if the market's aggregate demand was smaller, the cost of the vaccines would have been larger. Hence, in light of this description and given the evidence of large vaccine donations in the past, it seems reasonable to look at the vaccines industry as an appropriate context in which to apply the theoretical ideas of this paper.

Thus, some calculations can be made to approximate the total cost of the 78 million vaccines donated through the WHO initiative. In Table 3, we show two alternative calculations. First, an estimation of the average cost (for the representative pharmaceutical company) of 2.50 Euros per unit results in overall expenditures of 195 million Euros. Alternatively, suppliers may have claimed higher prices, which should not have been higher than 4.72 Euros, the price in Brazil. In this case, the total expenditure needed to carry out the WHO vaccine deployment initiative was 368.4 million Euros. As Table 3 makes clear, the potential financial resources from donations by countries and laboratories together in either of the two scenarios has to date surpassed this amount.

In summary, past experience reveals a generous desire to donate vaccines on the part of laboratories and countries. We venture that such behavior will be fostered by the expectation that the unit cost per vaccine may be reduced given external economies of scale associated with advance purchasing commitments. Indeed, the expectation of smaller costs helps explain the lower final prices in the provision of vaccines and the expansion in market size.

5 Concluding remarks

This paper advocates that implementing income transfer policies in the context of competitive markets may benefit society. The effectiveness of the policies in influencing demand in the desired manner, together with the presence of economies of scale in the industry, permit the realization of Pareto-improving effects.

An analysis of this issue, developed for a linear specification of the functions, has focused on two alternative model settings. First, the case of a linear transfer redistribution was examined, which concluded that the optimal transfer (in terms of a welfare increase) is achieved by adopting a linear transfer of the size associated with full-coverage of the market. This result depends on a condition that mixes the slopes of the demand and supply functions.

Second, we have shown how a redistributive transfer can be implemented in two steps. The analysis is encouraging because these types of transfers are always implementable and result in gains for every economic agent involved. If the transfer is properly arranged, the taxes collected in the first stage of the process do not harm incumbent consumers, whereas the subsidy enhances the welfare of new entrants. To avoid cheating, subsidies could be implemented through an auction process. This

Footnote 16 continued

Towse et al. (2015) propose methods to implement differential pricing systems to expand access to medicines in low- and middle-income countries, while increasing the overall welfare in the European Union.

results in a second wave of transactions, which expands the total social welfare and opens the market to individuals who were initially excluded. Three transfer policies are examined according to whether the government seeks to equalize a decline in price, maximize market coverage, and increase welfare. An empirical application for the vaccines industry is developed.

Our conclusions, even if stemming from an analysis of linear functions, are certainly valid beyond the linear framework. Nonetheless, studying the non-linear specifications of the functions merits further research. Unlike other papers, our results do not derived from correcting market failures associated with market power; they stem instead from the greater efficiency associated with benefits from external economies of scale and advanced purchasing commitments.

In summary, this paper has shown that, in the presence of external economies of scale, tax subsidy schemes can always be implemented in such a way that they improve the welfare level of every economic agent involved. This result supports an intervention when externalities are at work in the industry, even under the assumption of perfect competition. To illustrate a real case, this paper has examined the market of vaccines for influenza H1N1, which seems particularly appropriate for addressing the issue of external economies of scales.

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6 Appendix: main features of the vaccine industry and the WHO initiative

The activities and features that characterize the vaccine industry are extensively described by [Gordon et al. \(2008\)](#). This book explains that companies operating in the vaccine industry are engaged in very diverse types of activities, such as: research, development, manufacture, marketing, distribution, etc. Besides, developing vaccines is a difficult, risky and costly undertaking, which involves among other things clinical and process development.

According to this view, to judge the existence of external economies one should examine the above mentioned activities one by one.

In this book the authors stress that, at the manufacturing stage, some production processes in the vaccine industry are not scalable, implying that the unit manufacturing cost of vaccines does not significantly decrease as the production volume expands. Nevertheless, unlike manufacturing processes, the existence of external economies of scale has to be acknowledged at the research and development stage. Precisely, [Gordon et al. \(2008\)](#) point out that the market size is a key 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.” (p. 41). Also [Scherer \(2007\)](#) recognizes

the existence of economies of scale,¹⁷ although he seems to focus on the type of economies that are internal to the firm.

In any case, the existence of external economies of scale in this industry should not be a surprise, insofar as the success of the business depends on research activities. Indeed, once firms assume the heavy investments and capital risks associated to research, the large potential market size implies that the monetary returns are likely to compensate for the initial expenses.¹⁸

In conclusion, one may expect that the cost of developing this type of medicines decreases along with the market size: the larger amount of units produced, the cheaper the average costs. Accordingly, the vaccines industry seems an appropriate context in which to apply the main idea of this paper. Further information on the matter can be found again in: [Gordon et al. \(2008\)](#): “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, funneled through academia and contract research organizations.” (pp. 40–41).¹⁹

¹⁷ Some quotes from [Scherer \(2007\)](#) may be relevant in this regard: “Scale economies are likely to be most important, at least in assessing long-run costs, for new vaccines that must pass through lengthy and costly stages of pre-clinical research, product development, clinical testing, and regulatory evaluation. (...) The research and development costs for a completely new vaccine are said to be on the same order of magnitude as those for more conventional pharmaceuticals—estimated (...) at 400 million dollars out-of-pocket for a successful new product, averaging in the cost of failed projects. See [di Masi et al. \(2003\)](#). (...) Despite the lack of definitive data, it seems clear that front-end costs for a new vaccine may be measured in the hundreds of millions of dollars. These are essentially sunk fixed costs once production actually commences.” (p. 397).

¹⁸ [Gordon et al. \(2008\)](#) 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.” (p. 42). A similar argument is given by [Plotkin et al. \(2008\)](#) 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.” (p. xxi).

¹⁹ The issue of the market structure was addressed in Sect. 4, but deserves further exploration. Referring the whole pharmaceutical industry, [Matraves \(1999\)](#) highlights that: “Various structural changes have occurred in the pharmaceutical industry in recent years (...) [that] have had an important impact on the competitive process, and given the observed increase in advertising and R&D expenditure and the toughness of price competition, we predicted that concentration would increase. This increase would take place not at the national level, but at the global level. The evidence indeed showed no systematic pattern in changing market shares at the national and EU level, but concentration has significantly increased at the global level. (...) However, despite the pharmaceutical industry being [characterised by vertically differentiating products], there are nevertheless limits to how unconcentrated it can be. This is due to the existence of a firm size threshold, which has increased because of the following two factors. First we have seen an increase in the cost of innovation linked with the skewness of the rate of return on a new drug. Secondly, a global marketing/distribution network is necessary in order to exploit a new drug effectively. Both of these

Regarding the provision of vaccines and the role played by WHO, the following quote from the *Report of the WHO pandemic influenza A H1N1 vaccine deployment initiative* may help summarizing the actions taken to fight against 2009 influenza H1N1 outbreaks: “To ensure that developing countries were able to protect the health of their populations, WHO began to mobilize and coordinate the global donation of resources needed to deploy life-saving pandemic H1N1 vaccines and ancillary products to some of the world’s most vulnerable populations. (...) The subsequently established WHO Pandemic Influenza A H1N1 Vaccine Deployment Initiative coordinated the support of governments, foundations and manufacturers in facilitating access to pandemic H1N1 vaccines in countries eligible for assistance.” (p. 1).²⁰

Advance purchasing commitments is the other crucial aspect to understand how this industry operates. Past historical events proved the advantages of this procedure, by which governments commit themselves to buy a number of vaccines at a price previously agreed with WHO.²¹ The range of prices charged to the buying countries are settled depending on their economic status. According to WHO estimations, the price of the H1N1 vaccine ranged between 2.50 and 20 US dollars. The 2009 vaccine could be sold at around 10–20 US dollars in western economies, in the range of 5–10 in mid-level developing countries and in the range of 2.50–5 in the poor economies. Besides, the latter countries were extendedly funded by charities, global agencies, the World Bank, etc. Many people would agree that charging patients and countries by their ability to pay is better than providing free treatments.

This is precisely the usual way to encourage companies to development and manufacture vaccines, up to the level that meets the needs of population. Gordon et al. (2008, pp. 40–41) clarify that: “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

Footnote 19 continued

factors work against small firms. Furthermore, these factors are independent of the nature of the underlying technology in the pharmaceutical industry” (pp. 190–1). For the US vaccines industry, [Danzon and Pereira \(2005, 2011\)](#) predict the exit of all but one or very few producers in the long run.

²⁰ Another quotes from the mentioned WHO report summarizes the most relevant facts: “In April 2009, outbreaks of influenza-like illness occurred in Mexico and the United States. By 24 April 2009, it became clear that these outbreaks were related and WHO issued a health advisory. (...) On 11 June 2009, WHO declared the 2009 H1N1 influenza pandemic. (...) On 6 July 2009, the Secretary-General of the United Nations and the Director-General of WHO convened a meeting and released a Joint Statement expressing concern that the pandemic A (H1N1) 2009 virus could have a severe impact on low-income countries, and calling on the international community to provide assistance to help the least-developed countries to withstand these impacts. Donors attending the meeting requested that United Nations agencies and the World Bank develop a more detailed assessment. (...) In September 2009, governments and other donors began to announce their official support for efforts to secure pandemic H1N1 vaccines for countries without access. (...) On 18 September 2009, nine governments announced that they would share their pandemic H1N1 vaccine supplies with low- and middle-income countries. Among these, the United States pledged up to 10% of its supply of such vaccine; it was joined by Australia, Brazil, France, Italy, New Zealand, Norway, Switzerland and the United Kingdom.” (pp. 3–4).

²¹ Moreover, advance commitments may counterbalance the yield uncertainty that characterizes the vaccines production process. The yield uncertainty is precisely one key aspect examined by [Deo and Corbett \(2009\)](#), who consider that this feature contributes to a high degree of concentration in industries. Note also that self-enforcing commitments and income redistribution are used in models to analyze very different contexts: Cf.: [Filipovich and Sempere \(2008\)](#).

Table 4 Pandemic influenza H1N1

Country	Total doses (,000 units)	Population (Millions)	Coverage (%)
Afghanistan	500.0	23.0	2.2
Angola	2,030.0	16.6	12.3
Armenia	11.5	3.0	0.4
Azerbaijan	516.0	8.4	6.1
Bangladesh	15,600.0	156.0	10.0
Bhutan	65.0	0.6	10.0
Bolivia	900.0	9.4	9.6
Botswana	1,612.8	1.9	86.8
Burkina Faso	1,450.0	14.4	10.1
Cambodia	2,712.9	15.1	18.0
Cameroon	1,825.0	18.2	10.0
Central African Rep.	448.0	4.3	10.5
Chile	1,200.0	16.5	7.3
Comoros	65.0	0.8	7.9
Congo (Brazzaville)	400.0	3.7	10.8
Cook Islands	20.0	0.0	102.2
Cte d'Ivoire	2,197.0	18.9	11.6
Cuba	1,124.0	11.3	10.0
Republic of Korea	2,375.5	23.7	10.0
El Salvador	2,276.0	6.8	33.7
Equatorial Guinea	113.0	0.5	22.8
Ethiopia	3,000.0	81.0	3.7
Fiji	88.2	0.9	10.3
Gambia	163.8	1.7	9.8
Georgia	100.0	4.4	2.3
Ghana	2,300.0	23.0	10.0
Guatemala	1,300.0	13.0	10.0
Guinea	1,049.0	9.2	11.4
Guinea-Bissau	160.0	1.6	9.7
Guyana	275.0	0.7	37.2
Honduras	1,650.0	7.0	23.7
Kenya	730.0	36.6	2.0
Kiribati	10.0	0.1	10.0
Lao Republic	1,400.6	6.4	21.8
Lesotho	195.0	2.0	9.8
Mongolia	570.0	2.7	21.1
Myanmar	972.0	48.4	2.0
Namibia	216.0	2.0	10.6
Nauru	8.8	0.0	88.0
Nicaragua	750.0	5.5	13.6

Table 4 continued

Country	Total doses (,000 units)	Population (Millions)	Coverage (%)
Niger	1,374.9	13.7	10.0
Nigeria	2,880.0	144.7	2.0
Niue	1.7	0.0	104.3
Pakistan	3,100.0	151.8	2.0
Papua New Guinea	700.0	6.9	10.2
Paraguay	600.0	6.0	10.0
Philippines	3,400.0	93.6	3.6
Republic of Moldova	380.0	3.8	9.9
Rwanda	200.0	9.5	2.1
Samoa	30.2	0.2	16.9
Sao Tome Principe	16.0	0.2	10.3
Senegal	240.0	12.1	2.0
Seychelles	9.0	0.1	10.5
Sierra Leone	577.0	5.7	10.0
Solomon Islands	55.0	0.5	10.3
Somalia	54.0	8.3	0.7
South Africa	3,584.2	48.3	7.4
Sri Lanka	1,930.0	19.2	10.0
Sudan	700.0	34.5	2.0
Suriname	50.0	0.4	11.5
Swaziland	117.0	1.1	10.3
Tajikistan	670.0	6.6	10.1
Timor-Leste	117.0	1.1	10.5
Togo	663.5	6.4	10.4
Tokelau	1.6	0.0	104.6
Tonga	100.0	0.1	96.2
Tuvalu	1.0	0.0	10.0
Vanuatu	25.0	0.2	10.2
Zambia	256.8	11.7	2.2
Zimbabwe	1,250.0	13.2	9.4
Total	75,564.0	1,199.3	6.3

The WHO donation programme

Source: Report of the World Health Organization: Influenza A (H1N1) vaccine deployment initiative. (ISBN: 978 92 4 156442 7). Publications of the WHO at the web site: www.who.int

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

Table 5 Vaccines research units and producers in the world (2011–12)

	Company	Location	Business type
1	Acambis (sanofi pasteur)	Cambridge, US	Biologics/Vaccines
2	Acambis (sanofi pasteur)	Canton, US	Biologics/Vaccines
3	Acambis (sanofi pasteur)	Rockville, US	Biologics/Vaccines
4	Advanced BioScience Labs	Rockville, US	Contract Research and Manufacturing
5	Advaxis	N. Brunswick, US	Listeria Vaccine
6	Aeras	Rockville, US	TB Vaccines
7	Aeras	Cape Town, South Africa	TB Vaccines
8	Akorn	Decatur, US	Biologics/Vaccines
9	Akorn	Somerset, US	Biologics/Vaccines
10	AlphaVax	Durham, US	Biologics/Vaccines
11	Ancora Pharmaceuticals	Woburn, US	Glycoconjugate Vaccines
12	Antitope	Cambridge, UK	Immunogenicity, Antibodies, Vaccines
13	Arbovax	Raleigh, US	Vaccines
14	Bavarian Nordic	Mountain View, US	Vaccines
15	Bavarian Nordic	Washington, US	Vaccines
16	Bavarian Nordic	Kvistgard, Denmark	Vaccines
17	Bavarian Nordic	Berlin, Germany	Vaccines
18	Bavarian Nordic	Planegg, Germany	Vaccines
19	Bavarian Nordic	Bukit Timah, Singapore	Vaccines
20	Bharat Biotech	Hyderabad, India	Injectables, Vaccines, Contract Work
21	BiondVax	Ness Ziona, Israel	Universal Influenza Vaccine
22	Bioscience Vaccines	W. Lafayette, US	Adjuvant Technology
23	Celldex Therapeutics	New Haven, US	Small Molecules/Biologics/Vaccines
24	Celldex Therapeutics	Fall River, US	Small Molecules/Biologics/Vaccines

Table 5 continued

		Company	Location	Business type
25	14	Celldex Therapeutics	Needham, US	Small Molecules/Biologics/Vaccines
26	14	Celldex Therapeutics	Phillipsburg, US	Small Molecules/Biologics/Vaccines
27	15	CG Therapeutics	Seattle, US	Peptide Vaccine
28	16	CIBA Vision (Novartis)	Mississauga, US	Small Molecules/Vaccines/Biologics
29	17	Circassia	Oxford, UK	T-Cell Vaccines
30	18	Crucell	Gyeonggi-do, Korea	Vaccines and Antibodies
31	18	Crucell	Leiden, Netherlands	Vaccines and Antibodies
32	18	Crucell	Madrid, Spain	Vaccines and Antibodies
33	18	Crucell	Solna, Sweden	Vaccines and Antibodies
34	18	Crucell	Bern , Switzerland	Vaccines and Antibodies
35	19	Cytos Biotechnology	Schlieren, Switzerland	Therapeutic Vaccines
36	20	DanDrit Biotechnology	Copenhagen, Denmark	Cancer Vaccines
37	21	DynPort Vaccines (CSC)	Frederick, US	Vaccines/Biodefense
38	22	Emergent BioSolutions	Planegg, Germany	Biologic Vaccines
39	22	Emergent BioSolutions	Gaithersburg, US	Biologic Vaccines
40	22	Emergent BioSolutions	Rockville, US	Biologic Vaccines
41	22	Emergent BioSolutions	Lausing, US	Biologic Vaccines
42	23	EpitoGenesis	Walnut Creek, US	Vaccine Delivery Technologies
43	24	Etubics	Seattle, US	Vaccines
44	25	Flugen	Madison, US	Vaccines and Adjuvants
45	26	Genocoe Bioscience	Cambridge, US	Vaccines
46	27	Genphar	Mt. Pleasant, US	Vaccines
47	28	GeoVax	Atlanta, US	Vaccines

Table 5 continued

		Company	Location	Business type
48	29	GlaxoSmithKline	Westborough, US	Small Molecules/Vaccines/Biologics
49	29	GlaxoSmithKline	Durham, US	Small Molecules/Vaccines/Biologics
50	29	GlaxoSmithKline	Parsippany, US	Small Molecules/Vaccines/Biologics
51	29	GlaxoSmithKline	King of Prussia, US	Small Molecules/Vaccines/Biologics
52	29	GlaxoSmithKline	Marietta, US	Small Molecules/Vaccines/Biologics
53	29	GlaxoSmithKline	Philadelphia, US	Small Molecules/Vaccines/Biologics
54	29	GlaxoSmithKline	Angus, UK	Small Molecules/Vaccines/Biologics
55	29	GlaxoSmithKline	Beckenham, UK	Small Molecules/Vaccines/Biologics
56	29	GlaxoSmithKline	Dartford, UK	Small Molecules/Vaccines/Biologics
57	29	GlaxoSmithKline	Harlow, UK	Small Molecules/Vaccines/Biologics
58	29	GlaxoSmithKline	Hounslow, UK	Small Molecules/Vaccines/Biologics
59	29	GlaxoSmithKline	Irvine, UK	Small Molecules/Vaccines/Biologics
60	29	GlaxoSmithKline	Leigh, UK	Small Molecules/Vaccines/Biologics
61	29	GlaxoSmithKline	Maidenhead, UK	Small Molecules/Vaccines/Biologics
62	29	GlaxoSmithKline	Slough, UK	Small Molecules/Vaccines/Biologics
63	29	GlaxoSmithKline	Stevenage, UK	Small Molecules/Vaccines/Biologics
64	29	GlaxoSmithKline	Teesdale, UK	Small Molecules/Vaccines/Biologics
65	29	GlaxoSmithKline	Ulverston, UK	Small Molecules/Vaccines/Biologics
66	29	GlaxoSmithKline	Ware, UK	Small Molecules/Vaccines/Biologics
67	29	GlaxoSmithKline	Worthing, UK	Small Molecules/Vaccines/Biologics
68	30	GlycoVaxyn	Schlieren, Switzerland	Conjugates Vaccines
69	31	Haffkine Biopharmaceuticals	Mumbai, India	Small Molecules, Vaccines, Antitoxins
70	32	Heat Biologics	Miami, US	Therapeutic Vaccines
71	32	Heat Biologics	Chapel Hill, US	Therapeutic Vaccines

Table 5 continued

		Company	Location	Business type
72	33	immBio	Cambridge, UK	Vaccines
73	34	Immune Design	Seattle, US	DNA Vaccines
74	35	ImmunoBio	Raleigh, US	Vaccines
75	36	ImmunoCellular Therapeutics	Woodland Hills, US	Cancer Antigen Vaccines
76	37	Immunomic Therapeutics	Lancaster, US	Vaccines
77	38	Immunovaccine	Halifax, US	Vaccine Delivery Technology
78	39	Indian Immunologicals	Hyderabad, India	Veterinary Biologics, Vaccines
79	40	Inhibikase Therapeutics	Atlanta, US	Therapeutic Vaccines
80	41	Inovio Pharmaceuticals	San Diego, US	DNA Vaccines
81	41	Inovio Pharmaceuticals	Blue Bell, US	DNA Vaccines
82	42	Intellect Neurosciences	New York, US	Vaccines and Monoclonal Antibodies
83	43	Intercell	Vienna, Austria	Vaccines
84	43	Intercell	Gaithersburg, US	Vaccines
85	43	Intercell	Livingston, UK	Vaccines
86	44	Inviragen	Fort Collins, US	Vaccines
87	45	Jennerex	San Francisco, US	Viral Vaccines
88	45	Jennerex	Ottawa, US	Viral Vaccines
89	45	Jennerex	Pusan, South Korea	Viral Vaccines
90	46	Juvaris	Burlingame, US	Vaccines
91	47	LigoCyte	Bozeman, US	Biologics/Vaccines
92	48	Liquidia Technologies	Durham, US	Particle-based Vaccines
93	48	Liquidia Technologies	Morrisville, US	Particle-Based Therapies
94	49	MabVax Therapeutics	San Diego, US	Vaccines and Antibody Therapies

Table 5 continued

		Company	Location	Business type
95	50	MedImmune (AstraZeneca)	Mountain View, US	Small Molecules/Vaccines/Biologics
96	50	MedImmune (AstraZeneca)	Gaithersburg, US	Small Molecules/Vaccines/Biologics
97	50	MedImmune (AstraZeneca)	Liverpool, UK	Small Molecules/Vaccines/Biologics
98	51	Merck	San Francisco, US	Small Molecules/Vaccines/Biologics
99	51	Merck	Boston, US	Small Molecules/Vaccines/Biologics
100	51	Merck	Rahway, US	Small Molecules/Vaccines/Biologics
101	51	Merck	Whitehouse Station, US	Small Molecules/Vaccines/Biologics
102	51	Merck	N. Wales, US	Small Molecules/Vaccines/Biologics
103	51	Merck	Wayne, US	Small Molecules/Vaccines/Biologics
104	51	Merck	Elkton, US	Small Molecules/Vaccines/Biologics
105	52	Microbix	Mississauga, US	Biologics/Vaccines/Diagnostics
106	53	MimVax	New Orleans, US	Vaccines
107	54	MSD (Merck)	Carlow, Ireland	Vaccines
108	55	Mymetics	Epalinges, Switzerland	Vaccines/Antivirals
109	56	NanoBio	Ann Arbor, US	Topical/Mucosal Vaccines and Therapies
110	57	Neogen	Lansing, US	Animal Vaccines/Food Testing
111	58	NovaDigm	Grand Forks, US	Fungal and Bacterial Infection Vaccines
112	59	Novartis	San Diego, US	Small Molecules/Vaccines/Biologics
113	59	Novartis	Vacaville, US	Small Molecules/Vaccines/Biologics
114	59	Novartis	Duluth, US	Small Molecules/Vaccines/Biologics
115	59	Novartis	Cambridge, US	Small Mol/Vaccines/Biologics/Diagnostics
116	59	Novartis	Guadalajara, Mexico	Small Molecules/Vaccines/Biologics
117	59	Novartis	Greensboro, US	Small Molecules/Vaccines/Biologics
118	59	Novartis	Lincoln, US	Small Molecules/Vaccines/Biologics

Table 5 continued

		Company	Location	Business type
119	59	Novartis	E. Hanover, US	Small Molecules/Vaccines/Biologics
120	59	Novartis	Parsippany, US	Small Molecules/Vaccines/Biologics
121	59	Novartis	Suffern, US	Small Molecules/Vaccines/Biologics
122	59	Novartis	Charlottetown, US	Small Molecules/Vaccines/Biologics
123	59	Novartis	Dorval, US	Small Molecules/Vaccines/Biologics
124	60	Novartis Diagnostics	Emeryville, US	Small Molecules/Vaccines/Biologics
125	61	Novavax	San Diego, US	Biologic Vaccines
126	62	Nuron Biotech	Exton, US	Specialty Biologics and Vaccines
127	63	Okairos	Rome, Italy	T-Cell Based Vaccines
128	64	Organon (Merck)	Cambridge, US	Small Molecules/Biologics/Vaccines
129	64	Organon (Merck)	W. Orange, US	Small Molecules/Biologics/Vaccines
130	64	Organon (Merck)	Allentown, US	Small Molecules/Biologics/Vaccines
131	65	PaxVax	San Diego, US	Vaccines
132	66	Pevion Biotech	Bern, Switzerland	Vaccines
133	67	Pfizer	Andover, US	Small Molecules/Vaccines/Biologics
134	67	Pfizer	Sanford, US	Small Molecules/Vaccines/Biologics
135	67	Pfizer	Madison, US	Small Molecules/Vaccines/Biologics
136	67	Pfizer	Monmouth Junction, US	Small Molecules/Vaccines/Biologics
137	67	Pfizer	Pearl River, US	Small Molecules/Vaccines/Biologics
138	67	Pfizer	Rouses Point, US	Small Molecules/Vaccines/Biologics
139	67	Pfizer	Collegeville, US	Small Molecules/Vaccines/Biologics
140	68	Profectus Biosciences	Baltimore, US	Small Molecules/Viral Vaccines
141	68	Profectus Biosciences	Tarrytown, US	Small Molecules/Viral Vaccines
142	69	Protein Sciences	Meriden, US	Biologics/Vaccines

Table 5 continued

		Company	Location	Business type
143	70	Sandoz (Novartis)	Broomfield, US	Small Molecules/Vaccines/Biologics
144	70	Sandoz (Novartis)	Wilson, US	Small Molecules/Vaccines/Biologics
145	70	Sandoz (Novartis)	E. Hanover, US	Small Molecules/Vaccines/Biologics
146	70	Sandoz (Novartis)	Princeton, US	Small Molecules/Vaccines/Biologics
147	70	Sandoz (Novartis)	Boucherville, US	Small Molecules/Vaccines/Biologics
148	71	Sinovac Biotech	Beijing, China	Vaccines
149	71	Sinovac Biotech	Tangshan, China	Vaccines
150	72	Syngenta	Holly Springs, US	Small Molecules/Vaccines/Biologics
151	73	TapImmune	Bellevue, US	Vaccines
152	74	Vabiotech	Hanoi, Vietnam	Vaccines
153	75	Vaxart	San Francisco, US	Oral Vaccines
154	76	Vaxin	Birmingham, US	Biologics/Vaccines/Drug Delivery
155	77	VaxInnate	Cranbury, US	Vaccines
156	78	Vaxon Biotech	Paris, France	Cancer Vaccine
157	79	VBI Vaccines	Cambridge, US	Vaccine Development
158	79	VBI Vaccines	Ottawa, US	Vaccine Development
159	79	VBI Vaccines	Hull, US	Vaccine Development
160	80	Vibalogs	Cuxhaven, Germany	Contract Vaccines
161	81	Vical	San Diego, US	DNA Delivery/Vaccines
162	82	VitamFero	Cedex, France	Vaccine Technology
163	83	Vivaldi Biosciences	New York, US	Live-Attenuated Flu Vaccines

Sources: (<http://biopharmguy.com/vaccines.php>)

More information on Influenza Vaccines Market 2011–12: ASDReports.com (ASDMedia BV - Netherlands): (www.asdreports.com/companies-list.asp?id=14114&desc=World+Influenza+Vaccines+Market+2011-2021)

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 crucial for enabling new consumers to gain access to the market, thereby enlarging the industry size.

At the beginning of the program, the vaccines supply was limited whereas the aggregate demand was high. To ensure that the vaccines might be effectively used, eligible countries were enforced to satisfy a number of conditions established at front. First, countries had to submit a signed letter to confirm their interest in receiving the vaccines, which allowed WHO to estimate the global demand level. The procedure chosen by WHO to identify eligible countries was carefully implemented.²² Overall, the WHO programme delivered a cumulative amount beyond 78 million doses of vaccines, from which a total of 77 countries benefited, as Table 4 illustrates. The previous description suits well to the theoretical analysis of this paper.

Finally, more recent information on the vaccines market is shown in Table 5, which reports more than 80 companies that were identified as vaccine producers in 2012.²³

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²² It is well described in the *Report of the WHO pandemic influenza A (H1N1) vaccine deployment initiative*: “In August 2009, WHO began consultations with its regional offices to determine which countries would be eligible to receive donated pandemic H1N1 vaccine. Eligibility was based on the absence of domestic vaccine production and the lack of ability to purchase vaccine on the commercial market. Ninety-five low-income and lower middle-income countries and territories had no access to vaccine and were deemed eligible. Two additional countries (Chile and South Africa) were subsequently deemed eligible because of extenuating circumstances that increased the public health risk of pandemic H1N1 influenza—the catastrophic earthquake in Chile in February 2010 and the World Cup in South Africa in June and July 2010.” (p. 13). (...) “Of the 94 countries that expressed interest, 78 went on to complete all the remaining preconditions for vaccine supply.” (p. 15). (...) “As demand for vaccine began to decline in May 2010, WHO acted on its option of requesting manufacturers not to start production of some pending products to avoid wasting vaccines. Instead, it accepted additional donations of existing stocks of vaccines as needed to respond to the final peak in demand that occurred in August 2010. While demand fluctuated, the final median level of request remained close to 10% of the country population. However, due to differences in national circumstances there were very wide variations in both demand and subsequent vaccination coverage by recipient countries—with the latter ranging from 0.4–104.6% of the population. Significant factors in determining the final level of individual country deliveries were the timing of the request and the size of the country population. Countries that received more than 10% often requested their vaccines later, when supply levels were higher and increases could be accommodated. Regardless of timing, very small countries received quantities sufficient for more than 100% coverage simply because of minimum package sizes” (p. 21).

²³ The data are taken from Biopharmguy; alternatively, a more detailed information on the Influenza Vaccines Market 2011–2012 is provided by ASDMedia BV.

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