On Positive Externality

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Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6, 2013.

Abstract: This paper fills the gap of modeling positive externality cases when private marginal cost is higher than social marginal cost. Within this unique type of divergence of marginal costs two cases are scrutinized: social marginal benefit being higher than private marginal benefit, and vice versa, social marginal benefit being lower than private marginal benefit. Empirical case in study is commercial shellfish farming firm on the West Coast. The study shows that contrary to popular beliefs correcting for positive externalities does not always result in a positive welfare; however, it does result in a positive welfare for the study case of the particular shellfish farm.

Introduction

In the face of growing scarcity of natural resources and significant global environmental concerns, the correction of externalities has become very important. The motivation behind the studies of externalities is to provide valuation methods and viable mechanisms to induce economically efficient and optimal behavior of the market's and its agents' with respect to all costs involved: private and social. Such undertaking requires appropriate valuation of the welfare gains or losses due to externalities, as Stefano Pagiola of World Bank (2006) puts it: "Getting the science right." Furthermore, in a global market, producers of goods, consumers, the resulting externalities from the production processes as well as the potential environmental service providers that could offset the effects of the externalities may be all located in the different parts of the world; thus a robust framework on valuation of externalities is vital for well functioning markets. This paper models positive externalities, specifically cases when private marginal cost is higher than social marginal cost. The paper attempts to address the question whether correcting for a positive externality always results in a welfare gain. The theoretical framework to value externalities is derived and then followed up by the empirical case of a firm in shellfish farming industry.

An externality is a case when a certain action of one economic agent has an effect on the utility or production possibilities of another while this effect is not being captured fully by the market place (Just, Hueth and Schmitz 2004). Specifically, the most distinguishing attribute of externality is the absence of or poorly defined property rights, resulting in a good for which there is no market (Yandle 1998 and Anderson and Donald R. Leal 2001). An externality can be considered a market inefficiency or in some cases market failure (Bator 1958).

There are two types of externalities: negative and positive. Historically, the majority of the literature (Pigou 1932, Coase 1960, Buchanan and Tullock 1965, Browning 1977, Baumol and Oates 1977, 1985) deals with the negative externalities, i.e. cases when the cost of production does not reflect the indirect costs to those harmed by the product or byproduct. In other words, since the polluting producer does not pay these indirect costs, and thus they do not get passed onto the consumer of the goods, the social or total costs of production are larger than the private costs (Laffont, 2008). The work on positive externalities was initiated by Meade (1952); today it is often used in the works on environmental service payments like by Ferrero (2001), Andam, Ferrero, Pfaf, Robalino, and Sanches (2007), and more. However, currently positive externalities receive limited attention despite the fact that they are central to cost-benefit analyses. In addition to the limited coverage, over the past several years a general consensus has formed that correcting for positive externalities results in a welfare gain. One of the paper's goals is to investigate this assertion.

This paper models positive externality cases, and there are reasons to believe that, contrary to the popular beliefs, correcting for positive externalities does not always result in a welfare gain. The study theoretically derives welfare as a mathematical relationship between the elasticities of demand and supply, prices, and quantities. Its close analysis indicates that the welfare outcome strongly depends on the magnitudes of the elasticities of the demand and supply, prices and quantities of goods in the system. Based on these relationships exact conditions for the welfare gain are derived. Moreover, theory thus far treats externalities only in cases when social marginal cost is either higher or equal to private marginal cost (Schmitz, Moss 2010). The uniqueness of this paper is that it fills the gap of modeling positive externality cases when private marginal cost is higher than social marginal cost. Furthermore, within this unique type of divergence of marginal costs two cases are analyzed: consequently for higher and lower social marginal benefits than private marginal benefits. In this framework, a welfare benefit measure, value of the externality, and the optimal levels of production are derived.

The motivation behind the studies of externalities is the provision of the economically viable mechanisms to make the market and its agents' behavior economically efficient. Such undertaking requires appropriate pricing of externalities and optimal amount of compensation to the parties involved.

Literature

Externality literature spans for over a century, but majority of the literature deals with externality in a context of a negative effect on the society, such as air or water pollution, thus as a negative externality: Marshall (1922), Pigou (1932), Ellis and Fellner (1943), Coase (1960), Buchanan and Tullock (1965), Mishan (1969), Kapp (1969), Browning (1977), Baumol and Oates (1977, 1985), Raymond (2003) and Rude (2008), and many more. Moreover, theory thus far treats externality only in cases when social marginal cost is either higher or equal to private marginal cost (Schmitz, Moss 2010). This paper fills the gap of modeling positive externality cases when private marginal cost is higher than social marginal cost. Furthermore, within this unique type of divergence of marginal costs two cases are distinguished: social marginal benefit being higher than private marginal benefit, and vice versa, social marginal benefit being lower than private marginal benefit. These types of externalities are mainly modeled in the framework of producer on producer and producer on consumer cases. The paper shows that, despite popular believes positive externality does not always result in a net welfare gain. The paper derives specific conditions that involve a certain mathematical relationship between the elasticity of demand, elasticity of supply, prices, and quantities, which results in positive net welfare. Under those conditions, the study identifies the value of positive externality created in the market and shows the amount of compensation that the entity creating positive externality should be compensated with using the appropriate mechanism of transfer. The case in study is Commercial Hard Clam Culture Industry in Florida.

The disagreement in the literature on the subject of externality is neither about the actuality of the concept nor the necessity for its treatment. The discord is rather about the means of treatment or mechanism (i.e. the degree of governmental involvement) in corrective actions. Some like Coase (1960) and Buchanan and Tullock (1965), believe that externalities should not be corrected with government involvement, while some like Browning (1977) and Baumol and Oates (1977, 1985) believe that there is no other way but governmental intervention when dealing with externalities, and some people like Yandle (1998) and Anderson and Donald Leal (2001) believe that property rights is the vehicle for externality resolution.

Positive Externality: Framework and Motivations

One of the early formal treatments of positive externality was accomplished by Meade (1952) who described an example of apple and honey producers, non-increasing returns to scale case. The example since then has become classics in the welfare economics. Meade argued that honey producers' bees were consuming apple trees' nectar, but honey-producers did not compensate the apple producers for the good. Thus, the nectar was, firstly, a private depletable good and, secondly, an "unpriced" one (Meade, 1952). He showed that market was inefficient because private marginal cost of apple producer did not reflect unpaid fees to bee producer. In that particular example, out of the remedies available: tax, subsidy, and joint ownership – the last one, i.e. the reassignment of property rights, indeed won as the externality case resolution.

Now interestingly, whereas Meade covers producer one to producer two, P1 to P2, externality, he did not account for the reciprocal, P2 to P1, positive externality, namely, cross-pollination of the orchard's flowers by the honey producer bees - after all there would be no apples if there were no bees. Thus, having these two reciprocal positive externalities simultaneously in the same production process begs a question: which externality is larger in benefit, nectar or crosspollination? The question motivates the need for net welfare calculations of both to truly understand which externality, nectar or pollination, is the source of the inefficiency.

Interestingly enough, time has brought a solution to this question. In the past decade bees have become scarce, and whereas pollination used to be more or less natural process or a positive externality to certain fruit and vegetable producers, today it has become a priced service that is an important part of bee keeping business model (Willett and French, 1991). More specifically, honey producers charge farmers a fee to bring their bees to pollinate fields in need. In fact, in 1987 this service resulted in produced crops that were valued at $9.3 Million (Robinson, Nowogrodzki, and Morse, 1989). The number of colonies rented for cross-pollinating service climbed to 2.5 Million in 1998, which is 22.8% higher than in 1998 (Morse, Calderon, 2000). Clearly, such turn of events has shown that pollination has indeed a higher marginal benefit than that of provision of the nectar in a commercial environment. Although admittedly such development is due to the evolved scarcity of bees, the result is not surprising since "nature" itself designed nectar to be a natural attractor for the insects specifically as a mean to the goal of plant reproduction. In this commercial case, the market has administered its own solution to the inefficiency and no governmental intervention or property rights adjustment was needed, a fully priced fee based service has emerged to compensate bee keepers for the service that was once unpriced.

Given this intuition that externality might be better solved by the market, it is important to recognize that the drawback of market based solution is that it may take a substantial amount of time or a scarcity crisis. Thus, it is difficult to rule out that in some cases other remedies that may involve government may still be needed. Thus, in this paper, using geometric framework, we investigate in which cases and under which conditions such remedies would make sense because it is shown that correcting positive exernality does not automatically result in positive welfare.

Shellfish Industry

There are several environmental benefits that shellfish like mussels, clams, and oysters provide while being cultivated. They contribute to filtering surrounding water making it cleaner and fresher, and capturing the nitrogen and phosphorous run-offs from the agriculture (Gren et. al. 2009), and finally, they store carbon in their shells. Studies by University of Florida Shellfish Aquiculture Extension estimated that each clam removes on average 2.9 grams of carbon from the atmosphere and stores it for the long term in its shell. More specifically as carbon dioxide dissolves in seawater, clams, oysters, and mussels mineralize carbon as calcium carbonate, $CaCO_3$ (Baker 2010). Thus, clams, mussels, and oysters provide long term storage of carbon in contrast with plants, which release carbon back into the atmosphere while dying (Wehr and Sheath 2003). These species of shellfish have been proven to clean the ocean water from pollutants, toxins, impurities, and algae, thus improving water quality and creating benefits to fishery and coastal hotel industries as well local people who use beaches (Newell 2004). In the U.S. Congress, the Department of Commerce (DOC) and the National Oceanic and Atmospheric Administration (NOAA) have established laws and policies acknowledging expansion of aquaculture as a national priority (Proceedings of Coastal Zone 07, 2007).

Despite the environmental benefits that shellfish farming industry provides, one of the significant challenges of the West coastal shellfish farming industry is the regulation that limits production levels (Proceedings of Coastal Zone 07, 2007). Thus, one of the main goals of the study is to determine the optimal levels of production that are associated with maximizing the benefits created by Taylor Shellfish farm by identifying the value of the positive externalities. There is a reason to believe that the production level restrictions currently in place cause welfare loss to the consumers and the society in terms of nutritious food as well as cleaner water and environment. In addition, the developed framework has a policy component to determine the optimal level of compensation to the producer creating a positive externality. This measure pins down the economic value that the company has been forgoing and is willing to forgo if restrictions on production are relaxed, economically creating a double effect on the welfare of the society.

Data

Production data is to be provided by the Washington-based Taylor Shellfish Company, one of the oldest and largest producers of farmed shellfish in the country. The company commercially farm raises clams, oysters, mussels, and geoducks. Their customers include domestic as well as international commercial and retail buyers. The data are currently being collected from Taylor Shellfish Farms include: 10 year historical prices and quantities produced of each product, 10 year historical costs associated with each product. The average weight of shells will be determined by examining samples from the farm. The data on filtering speed and volume for each type of shellfish are provided by Environ International Corporation, a consulting group, who works closely with Taylor Shellfish. Cross-sectional historical costs data from ten fisheries are also being collected.

Historical data is used to determine the elasticity of demand and historical and/or cross-sectional data is used to estimate the elasticity of the supply – these determine curvatures of the demand and supply. Prices and quantities, obtained from Taylor Shellfish, are used to determine current production levels. The value of the positive externality determines the shift needed in production level to reach the optimal level.

Methodology

General Case

Firstly, a general case of positive externality with demand being total and private and social marginal cost diverging so that private one is higher, in other words public demand is not differentiated from private demand.

Figure 1.

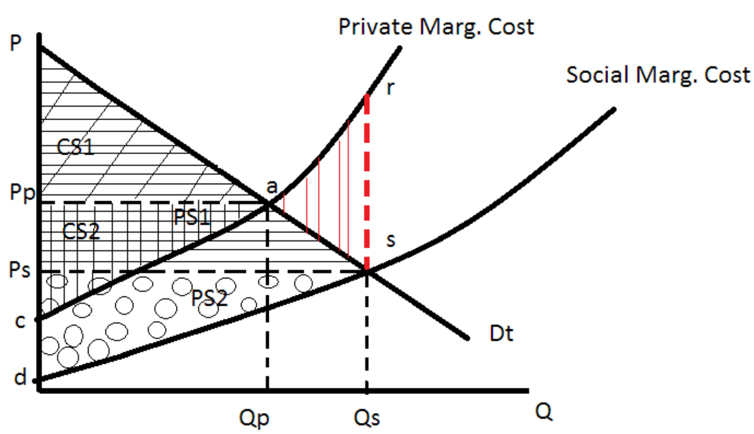
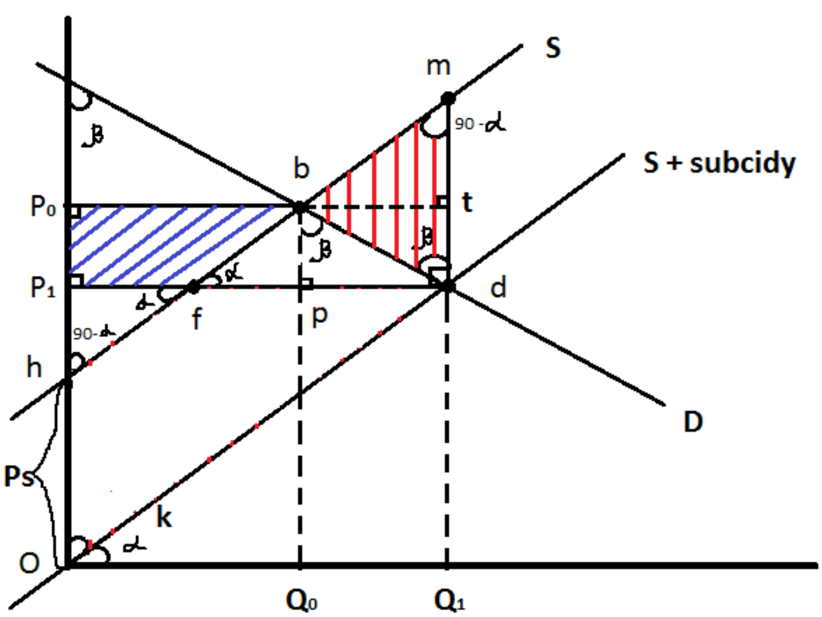


Figure 1 is an example when private investment has a good that's free or underpriced to other parties and society. Private cost far exceeds social cost. Clearly, producer surplus in case of price *Pp* and quantity *Qp* is smaller than in case of *Ps* and *Qs*, in other words triangle *acPp* is smaller than *sdPs*. However, consumer surplus in case of *Pp* and *Qp* is smaller than consumer surplus in case of *Ps* and *Qs* exactly by area of *asPpPs*. Then the amount of positive externality generated is a triangle *ars*. Thus, a form of subsidy maybe a possible solution, but the question is who should pay for it. Thus, in the next section mathematical analysis is presented – it shows that subsidy would not automatically result in positive welfare although if certain conditions are met positive welfare is positive. In the further section public and private demands are modeled separately.

Mathematical Treatment of General Case

The derivation of the amount of welfare shows that it is highly dependent on the elasticities of supply and demand as well as shifts in quantities and resulting prices (Figure 2).

Figure 2



$$Welfare = P_0P_1db + hofd - hodm$$

Since triangle *fdb* is common to both areas, welfare expression can be reduced to:

$$W = P_0P_1db - bdm \quad (1)$$

The derivations are provided in the Appendix.

Finally, going back to Equation (1) and substituting the three areas, welfare gain can be calculated:

$$W = \frac{1}{2}P_0P_1(P_0b + P_1d - P_0P_1(cot\alpha + tan\beta)) - \frac{1}{2}(P_0P_1)^2\, tan\beta\, (1 + \tan\alpha\, tan\beta)$$

$$= \frac{1}{2}P_0P_1(P_0b + P_1d - P_0P_1\big(cot\alpha + tan\beta + tan\beta\, (1 + \tan\alpha\, tan\beta)\big)(2)$$

We test the cases when W > 0.

$$\frac{1}{2}P_0P_1(Q_0 + Q_1 - P_0P_1\big(cot\alpha + tan\beta + tan\beta\, (1 + \tan\alpha\, tan\beta)\big) > 0 \ (3)$$

$$Q_0 + Q_1 - P_0P_1(cot\alpha + 2tan\beta + \tan\alpha\, tan\beta^2) > 0 \ (4)$$

$$Q_0 + Q_1 > P_0P_1(cot\alpha + 2tan\beta + \tan\alpha\, tan\beta^2) \ (5)$$

$$\frac{Q_0+Q_1}{P_0P_1} > cot\alpha + 2tan\beta + \tan\alpha\, tan\beta^2 \qquad (6)$$

This means that to realize a positive net welfare, the quotient of the sum of quantities (with and without the subsidy) and the amount of price change has to be larger than the following mathematical expression:

$$cot\alpha + 2tan\beta + \tan\alpha\, tan\beta^2 \ (12)$$

which is dependant upon supply and demand elasticities, α and β, respectively. The following sensitivity table (Table 1) presents numerical possibilities of that expression.

Table 1. Outcomes For $\boldsymbol{cot\alpha + 2tan\beta + \tan\alpha\, tan\beta^2}$ Depending On Different Elasticities.

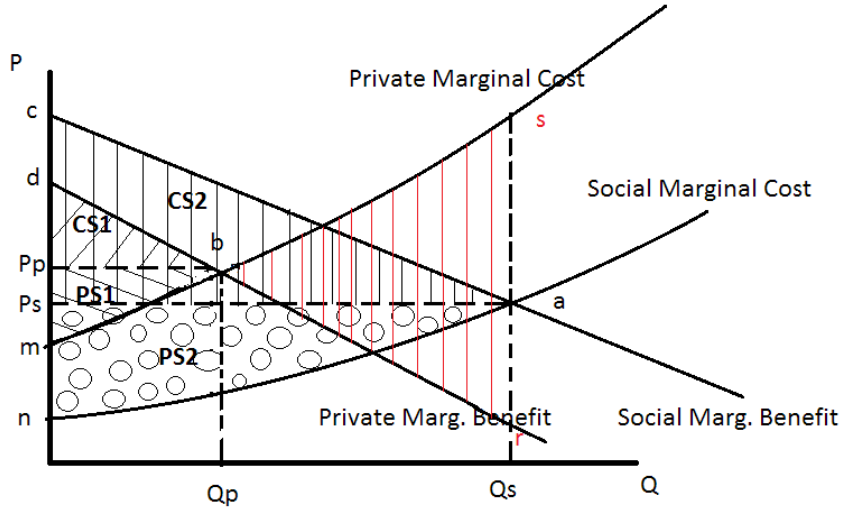
α \ β	10	20	30	40	45	50	60	70	80	90
10	6.03	6.42	6.88	7.47	7.85	8.31	9.66	12.50	22.69	7E+28
20	3.11	3.52	4.02	4.68	5.11	5.65	7.30	10.99	25.80	1E+29
30	2.10	2.54	3.08	3.82	4.31	4.94	6.93	11.59	31.64	2E+29
40	1.57	2.03	2.63	3.46	4.03	4.77	7.17	13.02	39.52	3E+29
45	1.38	1.86	2.49	3.38	4.00	4.80	7.46	14.04	44.51	4E+29
50	1.23	1.72	2.39	3.36	4.03	4.92	7.88	15.33	50.51	5E+29
60	0.98	1.53	2.31	3.48	4.31	5.42	9.24	19.15	67.63	7E+29
70	0.80	1.46	2.43	3.98	5.11	6.65	12.07	26.60	100.07	1E+30
80	0.71	1.66	3.22	5.85	7.85	10.61	20.65	48.48	193.93	2E+30
90	2E+13	8E+13	2E+14	4E+14	6E+14	9E+14	2E+15	5E+15	2E+16	2E+44

Assessing the table, it can be clearly seen that the smaller numbers of the table would serve better than the large ones, as they would increase the probability of positive welfare for given price and quantity changes. The table is color coded going from green to yellow in ascending order of numbers. Roughly speaking, the optimal angle of the supply curve is from 20 degrees to 80 degrees, whereas the angle of demand curve is more restrictive from 10 to 45. Of course, other angle combinations may also be possible but the sum of initial and final quantities should be proportionally larger than the price change, so that the quotient would still be larger than the number resulting from the Expression 12.

A Demand Shift Case

Furthermore, it is quite possible that the subsidy will influence a shift in demand. It is not a certainty, but a possibility in some cases, thus a case when social marginal benefit is larger than private marginal benefit while private marginal cost is higher than social marginal cost is demonstrated in Figure 3.

Figure 3.

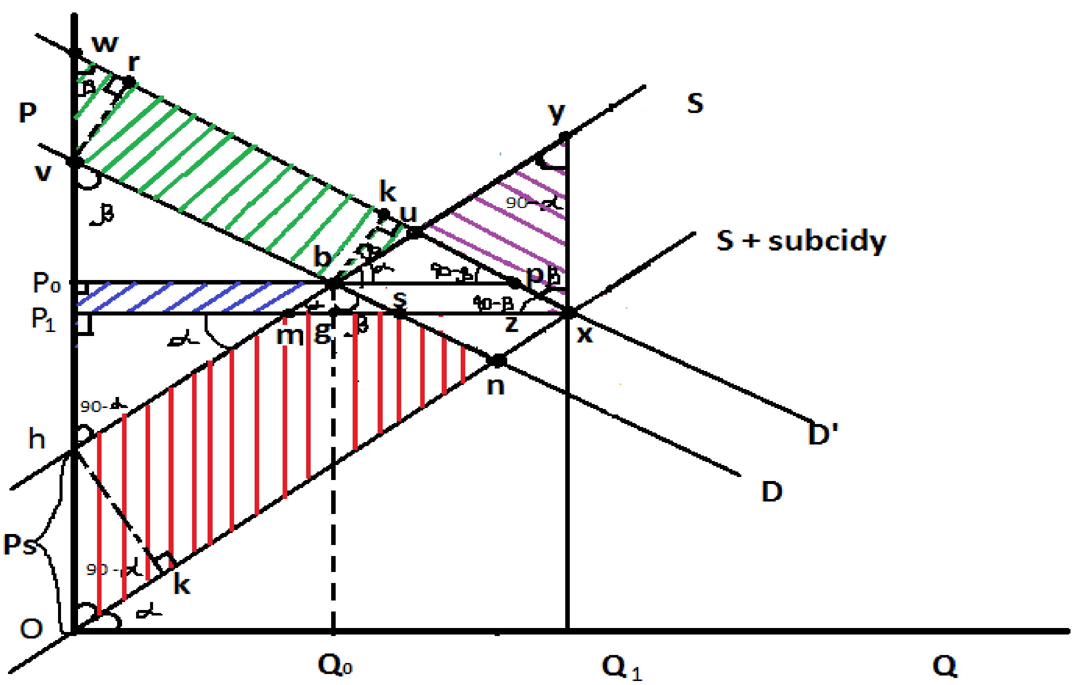


The amount of positive externality that a firm would create if producing at levels of quantity *Qs* and price *Ps* instead of *Qp* and *Pp* is a triangle *srb*. As can be seen from the Figure 4, the amount of that positive externality can be substantial. Thus, to move the firm from production at point *b* to production at point *a* consumer tax could be introduced to pay a subsidy to the producer.

Example of such case is clams industry. For instance, one of the leading clam industries is located in Cedar Key, Florida, where clams are grown commercially. There are 52 firms operating out Cedar Key as of 2007 and Florida clam processer and grower revenue was slightly over 31 Million during that year (Adams, Hodges, Stevens, 2008). The farming takes place on the ocean floor and one single term for growing clams is 4 months. Clams have been proven to clean the ocean water from pollutants, toxins, impurities, and algae, thus improving water quality and creating benefits to fishery and coastal hotel industries as well local people who use beaches (Wehr and Sheath, 2003 and Newell, 2004). Clams also remove carbon dioxide from the atmosphere and store it in their shells. For instance, in 2008 Cedar Key Clam Industry has removed 541 Metric tons of carbon dioxide. (Baker, 2010). Industries and people receiving benefits do not pay for the costs of the cleaning as there are no subsidies or price supports for the clam industry. Fisheries and hotel industry also do not pay any registered amount to the clam industry. Instead those costs are fully born by the efforts of the clam industry itself. The amount of positive externality is triangle *rbs*.

Mathematical Treatment Of The Case With Demand Shift

Figure 4



$$Welfare = P_0P_1mb + wvbu + bsxp - yux \quad (13)$$

$$Welfare = Q_0(P_0 - P_1) - \frac{1}{2}(P_0 - P1)^2 cot\alpha + vw\, Q_0 + \frac{1}{2}vw^2\frac{sin\beta\, cos\alpha}{\cos(\beta - \alpha)} + (P_0 - P_1)vw\, cot\beta - \frac{1}{2}oh(Q_1 - Q_0) + \frac{1}{2}vw\, oh\,\frac{cos\alpha\, sin\beta}{\cos(\beta - \alpha)}$$

$$= (Q_0 + vw\, cot\beta\,)(P_0 - P_1) + \left(vw + \frac{1}{2}oh\right) Q_0 + \frac{1}{2}vw(vw + oh)\frac{sin\beta\, cos\alpha}{\cos(\beta - \alpha)} - \frac{1}{2}(P_0 - P1)^2 cot\alpha - \frac{1}{2}oh\, Q_1 > 0$$

Again we are interested in the cases where welfare is larger than zero.

$$2(Q_0 + vw\ cot\beta\ )(P_0 - P_1) + \ Q_0(2vw + oh) + vw(vw + oh)\frac{cos\alpha\ sin\beta}{\cos(\beta - \alpha)} > (P_0 - P1)^2 cot\alpha + \ \ Q_1 oh$$

$$(P_0 - P_1)(2Q_0 + 2vw\ cot\beta - (P_0 - P1)cot\alpha) + \ 2Q_0 vw + oh(Q_0\ \ - Q_1 + vw\frac{cos\alpha\ sin\beta}{\cos(\beta - \alpha)})$$

$$+ vw^2\frac{cos\alpha\ sin\beta}{\cos(\beta - \alpha)} > 0\ (14)$$

The expression can be broken down into two parts for convenience, also the sum of the two still need to be considered as it well very well be that even one is less than zero in total with the other part it will still be positive.

$2Q_0 + 2vw\ cot\beta - (P_0 - P1)cot\alpha > 0\ (19)$ and $Q_0\ \ - Q_1 + vw\frac{cos\alpha\ sin\beta}{\cos(\beta-\alpha)} > 0\ (20)$

Now if $P_0 - P1$ is small enough, then Expression 19 will hold, and if $\frac{cos\alpha\ sin\beta}{\cos(\beta-\alpha)}$ is big enough, Expression 20 will hold with no problem. Table2 presents sensitivity analysis for the outcomes of $\frac{cos\alpha\ sin\beta}{\cos(\beta-\alpha)}$ given different scenarios for elasticities. Clearly, larger numbers will increase the probability of positive net welfare. Table 2 is color coded from green to yellow in descending order of the numbers.

Table 2. Outcomes For $\frac{cos\alpha\ sin\beta}{\cos(\beta-\alpha)}$ Depending On Different Elasticities

	Beta									
Alpha	10	20	30	40	45	50	60	70	80	90
10	0.17	0.34	0.52	0.73	0.85	0.98	1.33	1.85	2.84	5.67
20	0.17	0.32	0.48	0.64	0.73	0.83	1.06	1.37	1.85	2.75
30	0.16	0.30	0.43	0.57	0.63	0.71	0.87	1.06	1.33	1.73
40	0.15	0.28	0.39	0.49	0.54	0.60	0.71	0.83	0.98	1.19
45	0.15	0.27	0.37	0.46	0.50	0.54	0.63	0.73	0.85	1.00
50	0.15	0.25	0.34	0.42	0.46	0.49	0.57	0.64	0.73	0.84
60	0.14	0.22	0.29	0.34	0.37	0.39	0.43	0.48	0.52	0.58
70	0.12	0.18	0.22	0.25	0.27	0.28	0.30	0.32	0.34	0.36
80	0.09	0.12	0.14	0.15	0.15	0.15	0.16	0.17	0.17	0.18
90	2E-15	2E-15	2E-15	2E-15	2E-15	2E-15	2E-15	2E-15	2E-15	2E-15

Once, prices and quantities are known, and elasticities can be worked out, Benefit-Cost Ratio for the model is as follows:

$$\text{Benefit} - \text{Cost Ratio} \ = \frac{\overbrace{vwsx + P_0P_1px}^{Consumer\ Surplus} + \overbrace{ohmx}^{Producer\ Surplus}}{\underbrace{ohxy}_{Cost}} \quad (21)$$

Conclusion

The niche of this paper was to model positive externality with private marginal cost is higher than social marginal cost. The paper showed that compensating for positive externality does not always result in net welfare gain – at least in input subsidy framework. Case where subsidy does not cause a demand shift and case where the subsidy does cause a demand shift are covered. In both cases, it is shown that there are conditions dependent on quantity and price changes as well as elasticities have to be satisfied in order for the welfare to be net positive.

As it turns out from the examples, there are situations where previously uncompensated naturally occurring positive externalities eventually established a market and providers of what was considered an externality before at least in part were getting rents for the benefits that they created such as the case of honey producer modern business model. Whereas market solved the problem of inefficiency on its own, it took a bee scarcity problem and a lot of time. It can be conceived that not all externalities can have such leverage. Florida Cedar Key Cultured Clam industry example is presented as an active case where inefficiencies still exist since the clam production results in positive externalities to the societies, but they are not compensated for them. Therefore, cases of input subsidy were worked out as an attempt to explore whether it could serve as a solution. Data from clam production is still awaited since the survey for the industry in the area is scheduled for the beginning months of 2013. Once processed, the data will enter the mathematical model for the assessment of net welfare. Furthermore, the framework of Environmental Equivalent will also be explored to enhance the existing models.

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