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The Coase Theorem

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Abstract

Ronald Coase's 1960 paper, 'The Problem of Social Cost', is often referred to as the most frequently cited paper in the history of economics. Google Scholar estimates that it has been cited in books, academic journals, legal judgements and so forth about 50,000 times. The paper dealt with the issues created when the uses of property conflict – when one person's wish to use a resource for one purpose conflicts with another person's wish to use that resource for something else. For example, when a grazier's wish to use common land to farm cattle comes up against another farmer's wish to use the land to cultivate crops. Each farmer imposes a cost upon the other: if the grazier runs his cattle then the farmer incurs a loss of crops, and if the farmer erects a fence against the cattle the grazier experiences a fall in profits. Economists call the costs imposed by one user on another external costs or negative externalities. Legal systems and governments have created laws and taxes to deal with such situations. Coase argued that such interventions were not necessary. All that was required was to give one party a legal right to the resource. If this were done, then mutual bargaining between the affected parties would yield an outcome which was socially optimum, and this outcome *was the same whoever was allocated the property right*. This paper outlines Coase's reasoning and the assumptions underlying it, considering cases of production and consumption externalities. It concludes by surveying practical applications of Coase's Theorem.

Sturges versus Bridgman

In 1879 Mr Bridgman occupied a house at 30 Wigmore Street, London. His family had resided there for many years, and for the last sixty had manufactured sweets in a kitchen extension, which abutted onto a wall shared with the garden of 85 Wimpole Street. In the sweet-making process two marble mortars were employed and two wooden pestles, which were affixed to the wall adjacent to the garden of 85 Wimpole Street. In about 1870 a physician named Sturges moved to 85 Wimpole Street, where he conducted a medical practice.

The site of Bridgman's the sweet maker, 30 Wigmore Street (left) and Sturge's Medical Practice, 85 Wimpole Street (right)

After eight years, Sturges built a consulting room in his garden, the wall of which was boundary separating his garden from Mr Bridgman's kitchen. A problem then arose: Sturges claimed that the noise and vibrations generated by Bridgman's confectionary business, which ran from 10am to 1pm each day, so impacted his consulting room that it 'materially interfered with him in the practice of his profession' and prevented him from 'examining his patients by ausculation for diseases of the chest …'[1] He went to court to seek an injunction against Bridgman's use of his sweet-making machinery and the court found in his favour, ruling that Bridgman *was* causing a nuisance to Sturges and doing so in a residential neighbourhood where such a disturbance was not to be expected. Bridgman was ordered to stop using his sweet machinery. The building currently standing at 30 Wigmore Street dates to 1890. Did losing the case and his business cause Bridgman to sell up and lead to his house being demolished in rebuilt in a rather more luxurious style?

This case illustrates what can happen when property rights *conflict*. Sturges believed that he had a right to a quiet residence in which he could carry out his medical practice; Bridgman believed he had a right to use his property to make sweets. Each man's

[1] *The American Law Register* (1852-1891), Vol. 28, No. 6, New Series Volume 19 (June 1880), pp. 348-355.

use of his property imposed an external cost on the other. Clearly, Bridgman's machinery imposed a cost of noise and disturbance on his neighbour. But, in winning his case, Sturges imposed his externality of the need for quiet on his neighbour since it meant that Bridgman could no longer use his machinery in his business. Each imposed a cost on the other and the court ruled that that cost should fall on Bridgman and not the doctor. Now such external costs of a private activity are known to economists as *negative externalities*. The question then arises: from an economic point of view, was the court's decision the right one? Viewed from the perspective of maximising social welfare, was the outcome, that the doctor was free to practice as before and the confectioner was not, the optimal one?

The Coase Theorem

It was this question that Ronald Coase addressed in his extremely influential article 'The Problem of Social Cost'.[1] Published in 1960, the article is seen as initiating the modern study of law and economics. In 1966 George Stigler designated Coase's argument the 'Coase Theorem' and it is now recognised, says Steven Medema, as 'among the most influential and the most controversial ideas in the post–World War II history of economics.'[2] Coase's point was simple. Although the court found for Sturges and allocated to him the right to a quiet use of his property, in the process shutting down Bridgman's sweet making, this was not necessarily the right decision when judged in terms of social welfare, and, more importantly, was not the logical end of the matter. This was because Sturges and Bridgman could continue to negotiate over the terms on which their properties was used, and if they were free to bargain and if this bargaining was costless, the result that emerged *would* be in the social interest *and* was *not* dependent on the court ruling. This is the Coase Theorem, which is summarised in the words of Medema:

> If agents are rational and the costs of transacting are zero, resources will be allocated efficiently independent of how rights over those resources are initially distributed.[3]

Coase argued that, whatever the legal ruling, the ultimate outcome of the case ought to be the same if the two men had been free to rationally negotiate with no transaction costs. Wherever the court assigned the property rights in this case, the outcome should be the same – which is to say, the use to which a property is put does not depend on the allocation of property rights. Whether Sturges was given the right to practice without noise, or Bridgman was given the right to make confectionary with the attendant noise, the outcome would be the same and would be the social welfare

[1] R.H. Coase, 'The Problem of Social Cost', in R.H. Coase, *The Firm, the Market and the Law* (University of Chicago Press, Chicago, 1988).
[2] S. Medema, 'The Coase Theorem at Sixty', *Journal of Economic Literature* 2020, 58(4), 1045–1128.
[3] *Ibid*., p. 1046.

maximising outcome. Coase had suggested this idea in an earlier (1959) paper for the *Journal of Law and Economics* on the allocation by the US government of media broadcast licenses. He advocated that the rights to transmit on various frequencies should be auctioned to the highest bidders, and that problems of interference between the competing transmitters (a form of negative externality) could be solved by negotiations between the parties. Curiously, the *Journal*'s editor, Aaron Director, of the University of Chicago Law School, originally refused to publish the article since he disagreed with its conclusions. Coase demanded that he be allowed to defend himself, and in 1960 he met with Director, Milton Friedman, George Stigler, Arnold Harberger, and others in Chicago and in the course of the evening managed to win them over to his argument – which in retrospect is not surprising since the theorem provided the rationale for a free market as opposed to a state interventionist solution to negative externality problems. The result was that Director not only agreed to the publication of Coase's original article but suggested he do a more general one, and this was the 'Problem of Social Cost' published the following year.[1]

Let us see how this works. The court, in the case of Bridgman v. Sturges, allocated the property right to Sturges. By granting the injunction, Sturges could practice his doctoring in peace and Bridgman had to shut down his manufacturing operation. Yet this is not, necessarily, what would happen. It all depended whose activity generated the highest net profits. Suppose Sturges, when practicing in silence, realised from his business £1000 a year in profits (after paying for equipment, staffing, medicines etc), but that, due to the noise, his profits fell to zero as patients abandoned his surgery. So, the confectioner's noise reduced his net returns by £1000. Assume, next, that Bridgman's net profits were £2000 and that if the injunction stood his profits would fall to zero. From Bridgman's viewpoint an obvious solution presents itself: he could offer to pay the doctor £1000 to compensate him for his loss of profit and still be £2000 - £1000 = £1000 better off than he would be if he were compelled to shut down completely. Would Sturges accept this offer? Yes: his profit would be the same as before (£1000) so he would be no better or worse off. Of course, he might resent having his business terminated and insist on, say, £1500 to shut-down – making him £500 better off than before. The confectioner would pay this – since he would now be left with £500 in profit, which was still better than the zero he faced if forced to close down. Thus, if Sturges and Bridgman were free to make an economic bargain, the outcome would be that the doctor would close-down and the sweet business would continue.

Suppose, instead, that the court found in the sweet-maker's favour and allowed him to continue to make a noise. Could the doctor make an offer to Bridgman that would cause him to desist? No. The maximum amount the doctor would be prepared to pay to stop the noise would be £1000 since this is the amount he stands to lose anyway.

[1] *Ibid*., p. 1050-51.

But Bridgman's profit is £2000 and he won't give this up for a payment of £1000. He would only shut down if offered £2000, which Sturges cannot afford. So the sweet-making goes on and Sturges goes out of business. This, of course, is the same outcome as before: the sweet-making goes on and the doctoring stops.[1]

Thus, whether the allocation of the property right is made to the doctor or the confectioner makes no difference to the outcome. In either case, the sweet making continues and the doctor shuts down. And this is the outcome that the Coase Theorem predicts: the allocation of property rights has no effect upon the use to which the properties are put. As Coase stated the result:

> It is necessary to know whether the damaging business is liable or not for damage caused since without the establishment of this initial delimitation of rights there can be no market transactions to transfer and recombine them. But the ultimate result (which maximises the value of production) is independent of the legal position if the pricing system is assumed to work without cost.[2]

Let us take another example from Richard Posner's classic text, *Economic Analysis of Law*. Suppose a train company has a legal right to run steam locomotives along a stretch of track which passes by a farmer's fields. Sparks from the engine cause occasional fires among the crops growing within 100 yards of the track, the effect of which is to make those 100 yards of land uncultivatable, reducing the farmer's profits by $50 a year. These sparks could be stopped by fitting a spark-catcher to the locomotive costing $100 per annum to fit and maintain. Since train company has a right to run trains along its track it will *not* install the spark-catcher because to do so would reduce its profits by $100 a year. Could the farmer offer to pay for the spark catcher and so save his crops from damage? No: the spark-catcher costs $100, but the farmer is only losing $50 a year, so it would not be worth him making such a payment – he would be even worse off. The *maximum* amount he would be prepared to pay to the rail company to either fit a spark-catcher or to cause the company to run less or no trains at all is $50 and this is not enough to change the rail company's behaviour. The result is: the trains run, the sparks fly, and the farmer abandons cultivating within 100 yards of the track. Imagine, now, that the farmer is allocated the legal right to cultivate his land *without* the threat of having his crops burned by rogue sparks. What will happen now? Will the train company finally install the spark-catcher? No. The filter costs $100 and the farmer makes $50 profit on the land by the track. Clearly, the train company could offer the farmer, say, $60 to not cultivate the land within 100 yards of the track and so remove the fire threat. This is better for the train company since it avoids the extra $40 a spark-catcher would entail; yet it is also better for the farmer who instead of receiving $50 from the farmed land now gets $60.

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[1] For a good account of the Sturges v. Bridgman case and its economic implications, see F.H. Stephen, *The Economics of the Law* (Wheatsheaf Books, Brighton, 1988).

[2] Coase, 'Problem of Social Cost', p. 104.

The outcome, then, is: the trains run, the sparks fly, and the farmer does not cultivate within 100 yards of the track. *This is precisely the same outcome as when the train company had the legal right to run its trains with sparks.* Again, therefore, we see that the allocation of property rights between train company and farmer makes no difference to the outcome. As a result of bargaining between the train company and the farmer the most profitable use of the respective properties prevails: the profit from running the trains exceeded the profits from the 100 yards of farm-land and so the trains run. And this is the socially efficient outcome making the highest addition to net social welfare since the profits generated by the train company exceed the profits generated by the land next to the track.[1]

As a step towards generalising this result, we can amend it in a more realistic direction. Instead of simply saying the fire damage to the farmer is a fixed amount of $50 profit when the line is used, it is reasonable to suggest that the risk of fires along the trackside is linked to the frequency of trains on the line. If just one or two trains run the degree of fire damage to crops will be small; but as more trains run the damage to crops will increase. Thus, we can say that the loss in farmer profits will not be a fixed amount but will be positively correlated with the number of trains running per period of time – say a day. Similarly, we can say that the profit per train run will not be constant for the train company. Usually in economics we assume a downward sloping demand curve for a product. In this case, if a rail company wishes to run more trains per day then, to get passengers, it will need to lower the prices its charges for tickets. This means that as more trains are run per day then the marginal revenue and hence marginal profit per train (assuming that the cost of running each train is constant) will decline as the ticket prices steadily decline. **Figure 1** shows the marginal cost to the farmer in lost profits and the profit to the rail company per train as the number of trains run per day increases.

[1] R. Posner, *Economic Analysis of Law* (Little, Brown and Company, Boston, Third Edition, 1986), pp. 42-46.

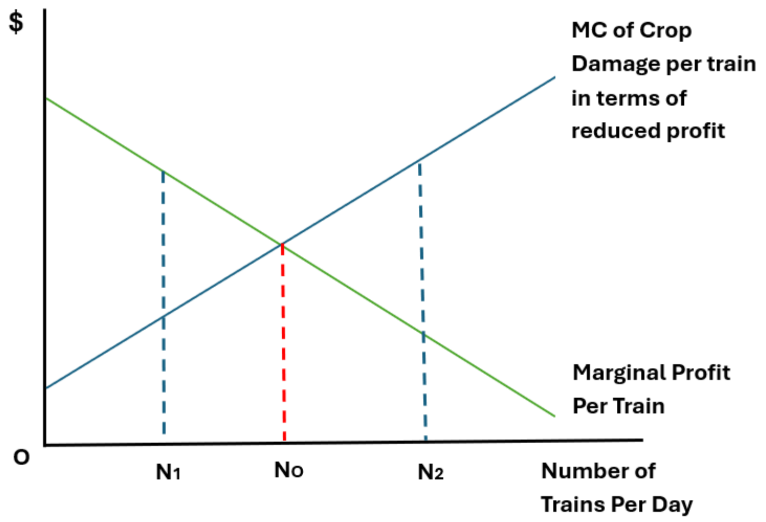

Figure 1. Marginal Profits and Marginal Losses from Running Trains

In this diagram, **No** is the socially optimal number of trains that will run each day and this is the number that *will* run so long as the train company and farmer are rational profit-maximisers and can bargain with zero transaction costs. Imagine, first, that the number of trains per day is less than **No**, say **N1**. At **N1** the profit to the rail company of running the last train exceeds the loss of profit to that farmer from that train. This means that more trains will run, whoever possesses the property right in this case. If the farmer has a right to no fires, then the train company can cover the farmers marginal profit loss and still be in surplus itself so it can pay the farmer to allow more trains. Similarly, if the train company has the property right to run the trains, then the farmer cannot afford to bribe the company to stop, since the most it is prepared to pay (equal to the marginal loss of profit from the damage to his crops) is less than the train company gets from running the train. So, more than **N1** trains will run. By contrast, suppose **N2** trains are running each day. This is not the socially optimal amount – too many trains are running. The loss in profits to the farmer of the last trains running exceeds the gain in profits to the rail company. If the railroad has the right to run trains, then the farmer will be better off (reduce his losses) if he were to pay the rail company a sum equal to the profit it gets from running the last train if it were to agree *not* to run it. And if the farmer has the property right, then the rail company profits are not enough to allow it to buy the farmers compliance – since the farmer's marginal profit loss exceeds the train company's marginal profit from running the last trains. So, if less than **No** trains are running more trains will run, whoever has the property right; and if more than **No** trains are running, less will run. The equilibrium number of trains arrived at will be **No**, at which point the marginal profit from running one more train to the rail company exactly equals the marginal cost in lost profit for the farmer. And this number of trains, **No**, is the social welfare maximising frequency.[1]

[1] *Ibid*., pp. 44-45.

Consumption Externalities

Both our examples thus far have referred to negative production externalities. Yet the same principles and outcomes apply to consumption externalities. Take an example of two neighbours in an apartment complex, one of which (A) likes to spend their evenings playing the piano while the other (B) dislikes piano music and prefers to enjoy peace and solitude.[1] The utility functions of the neighbours are:

$$U_A = U_A(W_A, P_A) \qquad \partial U_A/W_A > 0; \partial U_A/P_A > 0 \qquad (1)$$

$$U_B = U_B(W_B, P_A) \qquad \partial U_B/W_B > 0; \partial U_B/P_A < 0 \qquad (2)$$

Function (1) tells us that person A's utility depends on two things: their wealth (W_A) and the time they spend playing the piano (P_A). Both partial derivatives are positive, which means that an increase in wealth and an increase in time devoted to piano both make person A happier. Function (2) shows that this person, too, experiences greater utility as their wealth increases. But it also shows that their utility depends on how much person A plays the piano: the marginal utility of B with respect to A's piano playing ($\partial U_B/P_A$) is negative – every extra minute A spends playing the piano reduces the total utility of person B.

The contested issue here is piano playing: piano playing makes A happy and B unhappy and we again have a conflict of interests surrounding property rights. Does A have the right to enjoy practising the piano, or does B have a right to enjoy the tranquillity of their home? Coaseian analysis would seem to be relevant to resolving this conflict of interests.

Figure 2 summarises the issues involved. The MB line is person A's Marginal Benefit from playing the piano. Since we are assuming diminishing marginal utility, each extra hour of piano playing is taken to yield less additional happiness than the last and so the MB line is downward sloping until at **Ho** hours the marginal benefit of playing the piano an extra hour is zero. If A was to play beyond this point fatigue and boredom would probably cause the extra utility to be negative. So A, when left free to decide how much piano to play, will play to **Ho** where the marginal benefit is zero. Their total happiness from playing the piano is the area under the MB curve at this point, namely **a + b + d**. Note we have expressed the MB of piano playing in units of money. How can we do this – surely playing the piano is free for A? Simply, we ask A what they would be prepared to pay to be allowed to play the piano an extra hour. Since the first hour is the most pleasurable, they are prepared to pay the most for that; then a lower amount for a second hour, then a third, and so on until the **Ho** hour, when they are not prepared to pay anything since the MB is zero.

[1] This example is based on R. Perman, Y. Ma, J. McGilvray, and M. Common, *Natural Resource and Environmental Economics* (Pearson, Harlow, Third Edition, 2003), pp. 137-138.

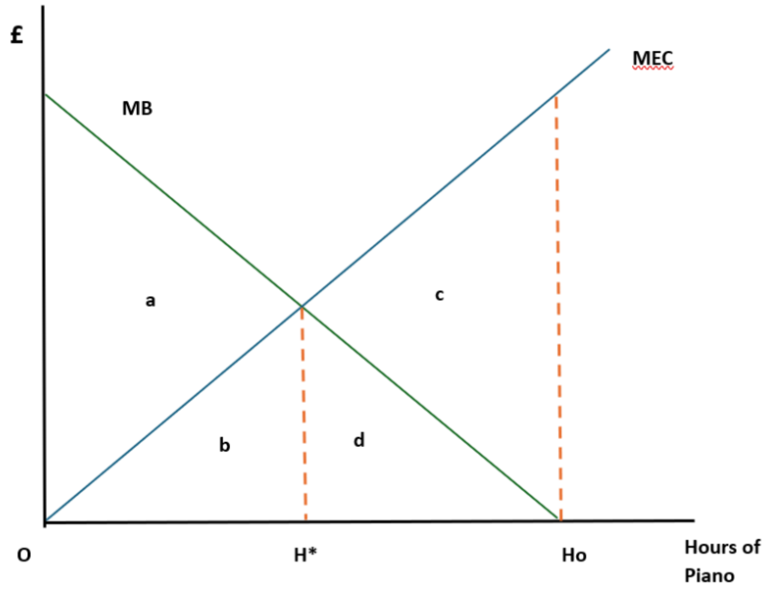

Figure 2. The Marginal Benefits and Costs from Piano Playing

The MEC line is the marginal external cost of playing the piano – which is the disutility incurred by neighbour B. As person A plays successive hours, the displeasure per extra hour experienced by B increases. One hour of piano practise they find irksome, but four or five hours are excruciating! Here, too, we have attached a monetary measure. In this case it is the amount B is prepared to pay A to *stop* an extra hour of piano. As the disutility per hour rises, so the amount B will pay to stop A playing an additional hour rises with it. If no such payments are made and A plays until their MB is zero at **Ho**, then B's total disutility from piano playing is the area beneath the MEC line, which is **b + d + c**.

The outcome of **Ho** hours of piano is not economically efficient. This is because at **Ho** the marginal cost to B of the last hour (MEC) significantly exceeds the marginal benefit to A of the last hour, which is zero. The total happiness of the two neighbours together is lowered by the last hour of practise. This is true for any of the hours beyond **H***, for all of which the MEC to B exceeds the MB to A. The area c represents the net welfare loss to the two neighbours from playing beyond **H***. Put another way: at any point to the right of **H*** the amount B is prepared to pay to *stop* A playing *exceeds* the amount A is prepared to pay to *keep playing*. In theory, if a trade could be arranged, for hours in excess of **H***, B would be prepared to pay A more than they need to be persuaded to stop playing. This is true up until **H*** hours – which is the socially efficient playing of the piano. For hours *less than* **H*** the MB of piano to A exceeds the MEC of piano to B and therefore A's piano playing increases the total utility of A and B. This net gain from piano playing is area a. Only at **H*** is the net gain exhausted and this is the optimal quantity of piano playing.

According to the Coase theorem, this outcome can be achieved by allocating a property right to either party. Suppose B was given the right to silence in their home.

Starting from the origin, this means that if A wants to play the piano they must compensate B at least to the amount that would leave B's net utility unaffected by their playing. The marginal cost of an hour of playing to B is the MEC line, so as long as A's MB exceeds this MEC then A is prepared to pay more to play for an hour than B requires to be compensated so A can gain from such an arrangement. So A begins to practise. As the hours of practise rise, so A's MB per hour declines and B's MEC rises until eventually **H*** hours are reached. At this point the amount A will pay B to be allowed to play an extra hour is exactly equal to the amount B needs to be paid to be compensated for the last hour. Since MB = MEC then this is the optimal amount of piano. Beyond **H*** the MB < MEC and A does not value additional hours sufficiently highly for them to be able to pay the compensation B requires to permit more piano. So **H*** is the stable equilibrium of this transaction. If, on the other hand, A has a right to play their piano when they want, then starting from **Ho**, the question is can B compensate A for *not* playing the piano? Yes B can do this – until **H*** is reached. For any number of hours beyond **H*** the amount B is prepared to pay A not to play exceeds the gain A expects from playing the piano and they will agree to desist. As the hours of playing decline the MEC of the piano for B declines and they are prepared to pay steadily less to get A to cut their playing, while the MB of piano playing to A rises and so the amount of payment they need to stop playing rises. Eventually at **H*** the MB and MEC are equal: the amount B will pay to A to cause them to reduce their playing by an hour is exactly equal to the amount A requires for them to give up the pleasures of an hour of piano. This, then, is the optimum number of hours. No further reduction will occur since the amount B will offer to get A to cut hours further is less than the money value of the pleasure A will get from playing for an hour and they would be worse off if they took the deal. Thus, A will not cut their playing any further and **H*** results – the exact same result in terms of hours of piano.

This is the same outcome of the Coase Theorem as we encountered in the previous two production examples. In each case bargaining between the affected parties results in the social welfare maximising output of the resources in question provided property rights are allocated to either of the parties and provided the process of bargaining is costless.

There are two important qualifications to this analysis that need to be considered. One is the matter of bargaining costs (more generally designated *transaction costs*) and the other relates to the outcome of the bargaining process.

Transaction Costs

If there are costs of bargaining (transaction costs) then the efficient outcome will probably not be achieved. These costs are summarised by Coase as follows:

> In order to carry out a market transaction it is necessary to discover who it is that one wishes to deal with, to inform people that one wishes to deal and on what terms, to

> conduct negotiations leading up to a bargain, to draw up the contract, to undertake the inspection needed to make sure that the terms of the contract are being observed, and so on. These operations are often extremely costly, sufficiently costly at any rate to prevent many transactions that would be caried out in a world in which the pricing system worked without cost.[1]

For example, in the case where A has the right to play the piano and B offers money to cause them to reduce their hours playing, then if each offer of money by B to reduce an hour involves using a lawyer to draw up the contract then the cost of the lawyer's fee will be subtracted from the amount B is prepared to pay A to cut their playing so they will be able to pay for fewer hours of reduction. The resulting number of hours will be somewhere to the right of **H*** and MEC will exceed MB and the outcome is *not* socially efficient – there will be a net welfare loss compared to H*.

Another set of problems arises over strategic bargaining behaviour. While it will be possible for A and B to agree terms in their mutual interests, it is likely than one or other party will engage in strategic behaviour to shift the terms of the deal in their favour. If B has the right to silence, then, knowing that A needs to practise their piano regularly to maintain the standard of their playing, they can hold out when A offers an amount exactly equal to their MEC and demand more so they will be better off than they were when silence reigned. A resists at first and only gradually might a deal be arrived at. This time delay adds to the costs of settling the bargain. When more than two people are involved – for example all ten neighbours in an apartment complex – then one person may *hold out* from agreeing a deal recognising that unless they approve no resolution can be achieved. They might demand such a high payout to allow piano playing that the whole deal collapses and no piano is played despite this being an inefficient outcome. Similarly, if the neighbours have to pay the pianist not to play, then each neighbour may be tempted to *free ride* – which means they decline to pay knowing that if the other neighbours pay A not to play more than a certain number of hours they will enjoy the benefits without having to pay themselves. If several neighbours free-ride like this, no payment will be made and A will play the piano for durations that are not welfare maximising.[2]

As can be seen, the theoretical optimality of the Coase solution may not be achieved due to the complexity, uncertainty, and positive costs of the negotiation process.

Endowment Effects

A central conclusion of the Coase Theorem is that, so long as property rights are allocated in a dispute over resource use, the *outcome* of the bargaining process is the

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[1] Coase, 'The Problem of Social Cost', p. 114.
[2] C. Veljanovski, *Economic Principles of Law* (Cambridge University Press, Cambridge, 2007), pp 47-49.

same whoever those rights are allotted to. In all the cases we have considered – Sturges versus Bridgman, the rail company and the farmer, the piano player and their neighbour – it made no difference to whom the property right was given: the output of sweet making or rail journeys or hours of piano playing were unaffected and in each case the socially optimal quantity was arrived it. In this sense, the allocation of property rights has no effect upon the use to which resources are put. Yet, this does *not* mean that the overall outcomes in each case are unaffected by the decision as to who to award the property right. In particular, there will be important differences in the allocation of *wealth* between the parties, and these wealth effects can influence the socially optimum outcome of the bargaining process.

To see how, consider the piano example again. Imagine that a judge rules that B's right to domestic peace trumps A's right to play their piano. In this case, if A is to play they must compensate B for the inconvenience entailed. Assuming that A pays B just the amount necessary to secure their acquiescence in their playing of the piano then they will have to pay B the amount **b** as shown in **Figure 2**. There is a transfer of wealth from A to B equal to **b**. B is now better off materially than before. By contrast, if A is awarded the right to play the piano, then B must pay A not to play up to Ho. We know that B must pay up to the amount **d** to A to cause them to reduce their playing to **H***. In this case there is a transfer of money wealth **d** from B to A. A ends up with more wealth than before. So, the allocation of property rights *does* impact the outcome: essentially, the recipient of the property right gains wealth as a result of the process. In the case of the doctor versus the sweet maker, since the court found in the doctor's favour then the sweet maker would have had to pay the doctor to accept the noise from his workshop – wealth would go from Bridgman to Sturges.

But we can go further: this endowment effect can influence the socially optimal output of the externality-generating activity – the world will *not* be unaffected by the allocation of property rights. This is because changes in income will affect the cost and benefit schedules relating to the consumption of a resource. In our music example, suppose the property right is accorded to the piano player. In this case, there will be a transfer of wealth from B to A since B has to pay A not to over-produce piano playing. But if piano playing is a normal good (which is likely) then A will want to play more piano if their income rises – that is to say, the amount A will be prepared to pay for each given hour of piano playing will increase and the MB line will shift upwards. In the below diagram it shifts to MB1.

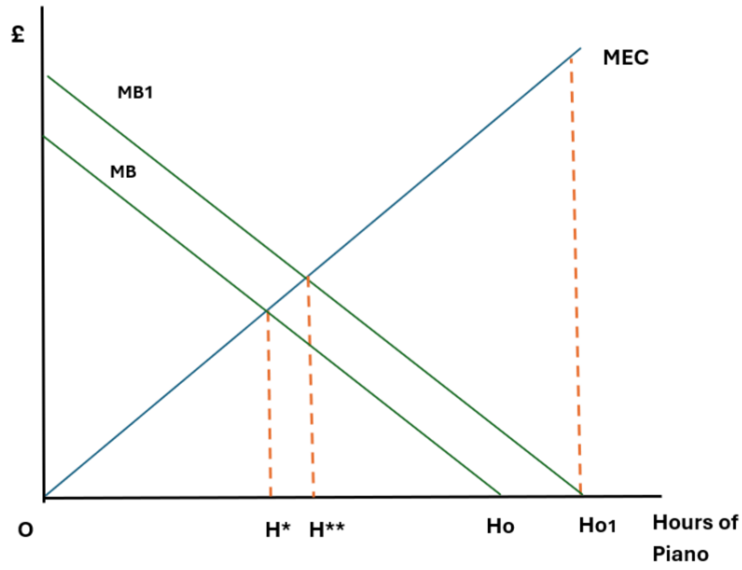

Figure 3. Endowment Effect of Transfer of Wealth to Piano Player

Since A's MB line for playing piano has shifted from MB to MB1, the socially optimal quantity of playing time increases to **H****. B will no longer be able to pay A to reduce consumption of piano music to **H*** but only to **H****. Indeed, since B is now poorer, their demand for silence will diminish (if this, too, is a normal good) and their MEC line will shift downwards, meaning that the socially optimal outcome will be further to the right that **H**** and even more piano will emerge from the negotiating process. By contrast, if B is granted the right to a silent home then A will need to pay B for the right to play piano and B will become richer. This causes their demand for peace and quiet to increase and so the MEC line will shift up and the optimum amount of piano will be *less* than **H***, especially as A (who is now poorer) will not be able to pay so much to play the piano and A's MB line will shift inwards. This outcome is shown below.

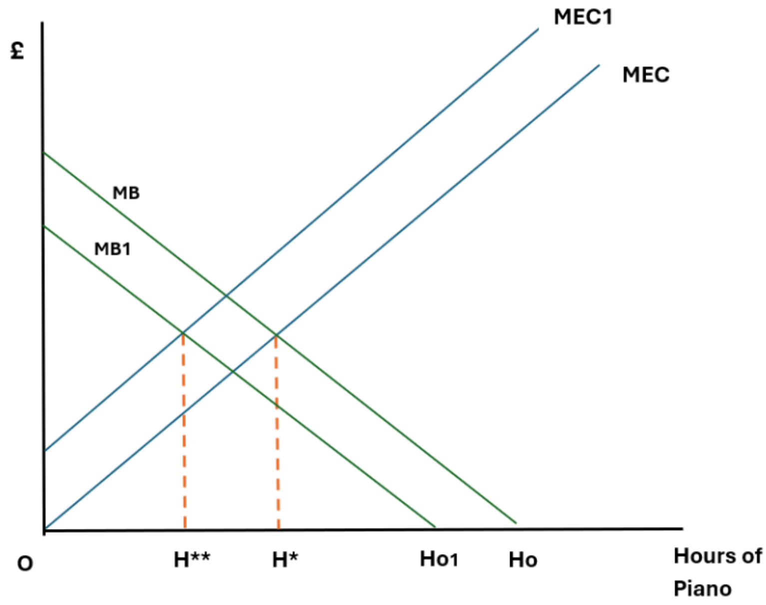

Figure 4. Net Endowment Effects when Piano Player Compensates Neighbour

This diagram shows the total effects of the wealth transfer. Since B has gained income their demand for quiet increases and the marginal cost to B of piano playing shifts up tom MEC to MEC. At the same time, A has become poorer since they must pay B to play their piano and hence the amount they are prepared to pay for any amount of piano has declined from MB to MB1. As a result, bargaining between the two neighbours will result in the socially optimal quantity of piano **H****, a significant reduction compared to the outcome without endowment effects (**H***). 'The endowment effect', writes Veljanovski, 'does not undermine the validity of the Coase Theorem. The outcome of bargaining under zero transactions costs will still be efficient but different under the two legal regimes, because the valuation of losses alters.'[1] On grounds of pure equity, it might be concluded that, when rights to property are contested, it is preferable to award the property right to the poorer of the two claimants since, while the efficient outcome will be achieved in either case, the result will be a transfer of wealth from the richer to the poorer party.

Production Externalities

We now consider the case of production externalities in more detail.[2]

Imagine there is a factory whose production process involves generating smoke which damages the properties and air quality of residents within the surrounding mile. Each extra unit of output the factory produces yields an extra unit smoke and extra profit for

[1] *Ibid*., p. 45.
[2] The example which follows is based on Veljanovski, *Economic Principles of Law*, pp. 43-44.

the firm. We assume that the extra profit per unit of output (and hence smoke) produced declines since the factory must sell each additional output at a lower price (its demand curve is downward sloping). The factory's marginal profit curve for smoke production is therefore as follows.

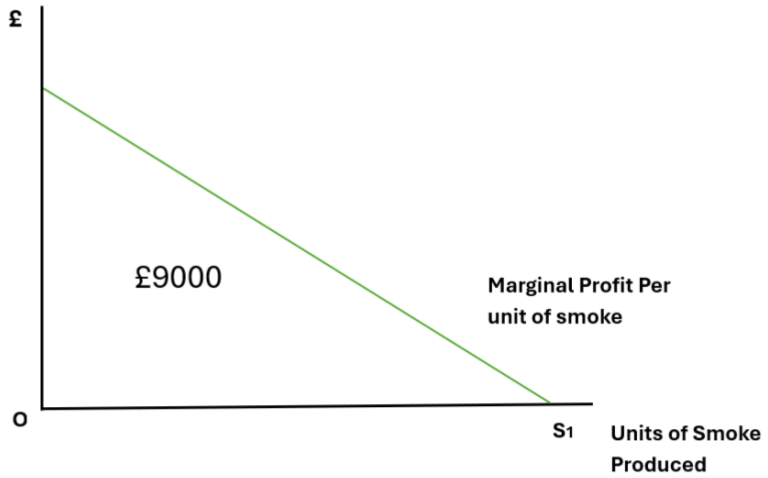

Figure 5. Marginal Profit Curve for a Smoke Producing Firm

We see that the factory's marginal profit curve for smoke is downward sloping, declining as output and smoke increase, until at S1 the marginal profit from extra output is zero. If left to follow its own devices, the factory would maximise profits by producing S1 of smoke, its profits being £9,000.

Now consider the impact of smoke on local residents. We assume that each additional unit of smoke added to the atmosphere increases the harm done to local residents – the first unit of smoke created may make little difference to their lives and properties, but as the output of the factory increases and more and more smoke is put into the air, then each extra unit is more damaging to health and takes a greater toll on buildings – blackening windows, cars, washing, and so forth. Hence the marginal cost to residents is a rising function of the quantity of smoke produced.

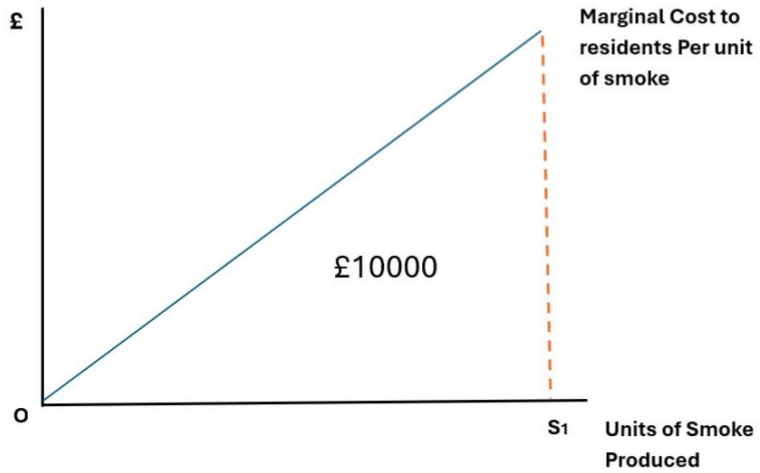

Figure 6. Marginal Cost to Residents of Greater Amounts of Smoke Pollution

Figure 6 shows the rising marginal cost of smoke to residents as more is produced. The monetary cost reflects the loss in earnings due to ill-health, the cost of medical care, the cost of cleaning windows and cars more often, and so on. The line stops at S1 since this is the maximum amount of smoke the factory will wish to produce. The area beneath the MC line is the total cost to residents of the smoke – which is valued at £10,000, this being, again, the total amount that residents would be prepared to pay to experience zero quantities of smoke.

Clearly, we have a conflict over property use. The factory gains from using the air to release the smoke generated by its production process, while the residents gain from having clean air without smoke damage. The interests of one are at odds with the interests of the other. Judging the matter economically, the first step is to determine the socially optimal level of smoke pollution. This is not zero: the reason is that, while the smoke undoubtedly damages the interests of the local community, the smoke is a by-product of making products that society values. The factory sells its output for a profit and this tells us that the value of what it produces exceeds the costs of making that output. Consumers of the factory's products value its output and are prepared to pay for it and the money they pay exceeds the regular costs of production – the inputs of labour, machinery, raw materials. If the factory were told to shut down all this net benefit from producing the products that generate the smoke (£9000) would be lost to society. Yet the fact remains that these products and the smoke they generate come at a cost to those people who experience its adverse effects. Since the external cost to local residents totals £10,000 at S1, and this exceeds the net profits at S1 (£9,000), we see that S1 cannot be the optimal quantity of smoke – there would be a net welfare loss of £1,000. So what is the socially optimal output of smoke? To see this, we simply combine the benefit and cost lines as follows.

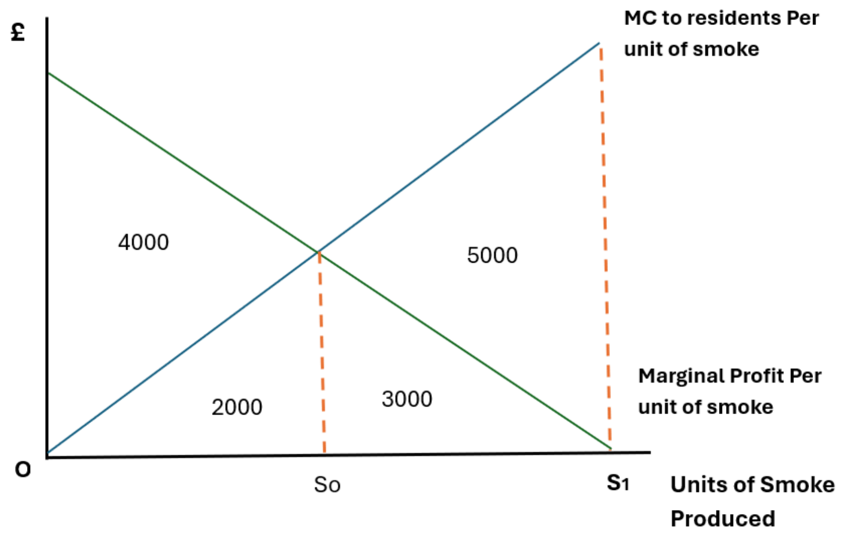

Figure 7. Marginal Profit and Marginal External Cost of Smoke Output

This diagram shows that the social welfare maximising quantity of smoke is **So**. At this point, the marginal benefit to the factory (and hence society) of the last unit of smoke produced is equal to the marginal cost of that unit for local residents. This is the efficient outcome. If less than **So** smoke was produced, then the marginal benefit of the smoke would exceed the marginal cost, and there is a net social gain from generating more smoke. If more than **So** smoke is produced, then the marginal cost to local residents exceeds the marginal gain to the factory, and net welfare is reduced. Only at **So** is the marginal gain and loss equal and this is the total welfare maximising output of smoke by the factory.

But will this be the amount of smoke generated? According to the Coase Theorem the answer is yes – provided property rights are allocated either to the factory or the residents. Assume that the right to pollute is granted to the factory. Can the residents offer enough money to stop the firm polluting? Not initially. To the left of **So** the marginal profit from the smoke enjoyed by the factory is greater than the marginal cost incurred by the residents. The total cost to the residents of pollution up to **So** is £2000, but the firm makes a profit of £6000. The maximum amount residents would pay to stop the smoke is £2000, but the factory's profits are £6000. If the factory agreed to the residents' offer it would be £4000 worse off – so it won't agree and the pollution goes on. The net benefit to society from the smoke is £6000 - £2000 = £4000. But if the pollution goes beyond **So** the outcome changes. Beyond **So** the marginal cost to residents *exceeds* the gain to the factory. If the residents offered the full amount of their marginal cost to the factory to stop making any more smoke beyond **So** the factory would agree since it would gain more money from the residents than it would give up in profits. For example, if the factory produced **S1-So** extra smoke, the cost to residents is £5000 + £3000 = £8000, which exceeds the profit gain to the factory, which is £3000. Hence the residents will be willing to pay the factory not to produce more smoke and the factory stops polluting at **So**. And this is the optimal amount.

By contrast, if the residents have the right to smoke-free air, then the factory will need to compensate the residents if it is to persuade them to be allowed to produce. It is in its interests to do so. As we have seen, the profit gain to the firm of producing **So** of smoke is £6000, and this means the factory can pay £2000 to compensate the local residents for the smoke damage and still be £4000 better off than if it did not produce at all. Hence a profit-maximising firm will do so. But it won't seek to pollute beyond **So** since the marginal benefit of smoke is less than the marginal cost and the factory cannot compensate the residents for their losses and still make a profit. Thus, it will not do so. Again, therefore, we arrive at the social optimum quantity of smoke, **So**. This confirms Coase's argument: the initial allocation of property rights between the factory and the residents makes no difference to the outcome provided both sides are free to trade and there are no costs of trading as such.

The smoke quantity **So** is said to be Pareto Efficient. This means that once at **So**, no party can be made better off without making another party worse off. So, as we saw, the factory would be better off if it produced more than **So** smoke, but the gain of the factory from this extra smoke is less than the damage incurred by the residents. And this means that the factory cannot compensate the residents from the extra smoke damage. Hence, if the factory produces more than **So** it will be better-off but the residents will be worse off – which means a smoke output beyond **So** is *not* Pareto efficient – someone is worse off (in this case the residents). But if the smoke quantity is below **So** this is not Pareto Efficient as by increasing smoke production it is possible to make the factory better off without making the residents worse off. This is because the extra profits made by the factory are sufficient to fully compensate the residents for their losses and still leave the factory better off. The factory has gained and the residents are no worse off: so there is a Pareto improvement. Only at **So** is no Pareto improvement possible.

Interpreting Externalities Diagrams through the Coase Theorem

The analysis we have thus far expounded can be applied directly to the negative externality diagrams familiar from any introductory economics textbook. These diagrams involve distinguishing between the private cost to a firm of making a product and the social cost to society – which is the sum of the private cost to the firm *plus* the additional costs imposed on third parties by the firms' activities. Since the third-party cost is not included in the transaction (like the smoke generated by the factory), too much pollution is created.

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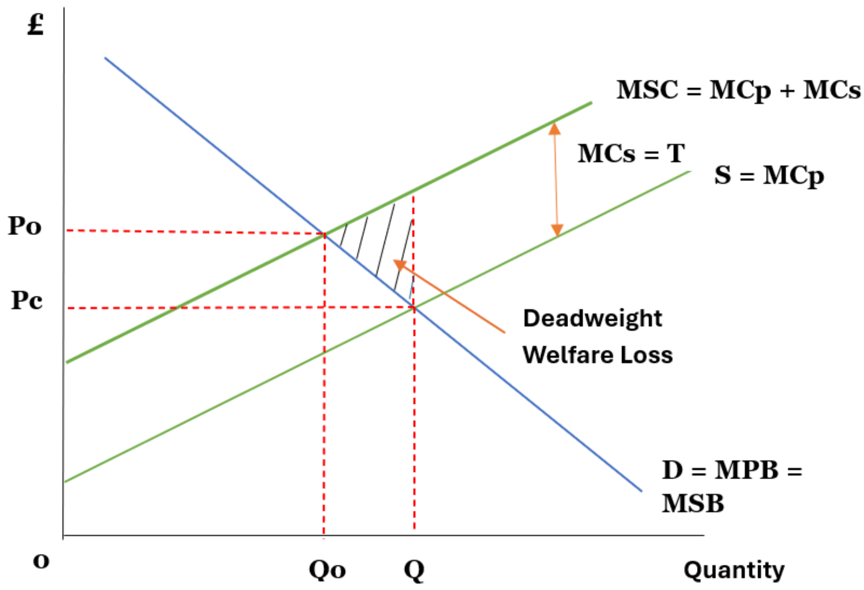


Figure 8. Market Failure due to Negative Production Externalities

In **Figure 8** the cost to the firm of making a product is shown by the S = MCp line, while the demand for the product is the D = MPB = MSB line. The demand curve D shows the amount consumers are prepared for each unit of the product, which reflects the Marginal Private Benefit (MPB) they expect to derive from the good. We assume that the MPB is equal to the Marginal Social Benefit (MSB) and there are no externalities from consuming the product. However, we assume that *producing* the good has negative effects on the wider society (e.g. air pollution) which we call Marginal Cost Social (MCs). Hence the total Marginal Social Cost (MSC) of producing the good is the Marginal Private Cost to firms plus the Marginal Cost Social to society, which equals MSC = MCp + MCs. The firm doesn't take these marginal external costs into account and therefore produces output **Q**, where demand equals supply and MPc = MPB = MSB = Price Pc. This is the equilibrium output and price for the firm. But this is not the social welfare maximising output since at output **Q** the marginal social cost of the last unit produced exceeds the marginal social benefit to society MSC>MSB). The last unit produced *reduces* total social welfare. This is true of all units produced beyond **Qo** and **Qo** is the social welfare maximising output since, at **Qo**, MSB=MSC. At this output social welfare is maximised. By producing beyond **Qo** to **Q** the firm is reducing social welfare by the amount of the shaded area, which is called the *Deadweight Welfare Loss*. By itself, a profit maximising firm will always produce at **Q** and will always produce more than the social welfare maximising amount. The problem arises since the pollution the firm creates, while imposing a negative externality or cost on society, does *not* produce a cost to the firm since it is free to pollute. There is no price to pay for pollution so the firm does not include the external costs of its actions in its output decision. Such an outcome is considered a market failure of the price mechanism.

One of the first economists to recognise this problem was Arthur Pigou. In his *Economics of Welfare* (1920) he observed that it was possible for the marginal social benefit of additional output to be less than the marginal private benefit, in which case an excessive output would be produced from a social viewpoint.[1] To correct this, he posited the imposition of a certain rate of tax which would diminish the marginal private benefit of the producer and cause them to reduce output to the optimum amount. Such a corrective tax is called a *Pigouvian Tax*. In **Figure 8** such a tax would be the unit tax **T**, which is equal to the marginal negative externality of production MSc. If imposed on the producing firm it would raise the cost of production per unit by **T** so that the firm's cost function is now **MSc + T**. And since **T** is equal to the negative external cost in society, the firm would now produce **Qo**, where **MPc + T = Po**, which is the social welfare maximising output where MSB=MSC. An accurately assessed tax could therefore cause the market mechanism to produce the optimum quantity of output.

In this sense, a free market system left to itself would *not* produce the optimum quantity of output whenever there are negative externalities of production (such as air pollution, noise, carbon generation), and to correct this market failure the state needs to intervene to impose a cost on the firm through a tax equal to the marginal external cost. What Coase did in his 1960 article is show that a tax was not the only solution to this problem. Rather, the problem of market failure in such cases of negative externalities of production (or consumption) could be eliminated so long as the state can prescribe and uphold property rights. Once this is done, the efficient solution to the externalities problem can emerge through free bargaining between those affected, without the need for state intervention. We can explore this through another example.

Suppose a lake potentially used by two firms: a steel plant and a fishing business. The steel plant, if it produces steel, will release polluted water into the lake, which will damage the fish and reduce the income of the fishing firm. This is a typical example of a conflict over the use of a resource. The solution, as we have seen, is to give one of the party's rights over the contested water. Let us suppose that the steel firm owns the lake and can pollute as it wishes, but that it hires out the use of the lake to the fishing firm.

[1] A. Pigou, *The Economics of Welfare* (Macmillan, London, Fourth Edition, 1932).

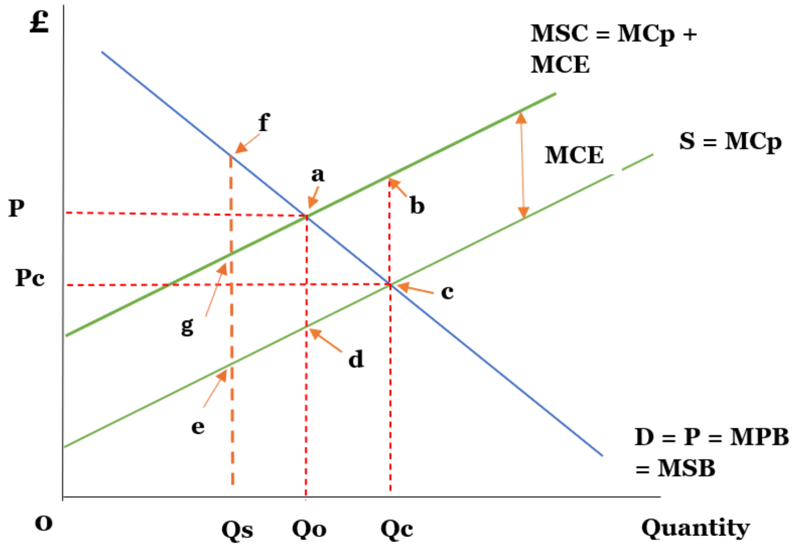


Figure 9. Compensating for Negative Externalities: the Coase Theorem

In this diagram the steel firm, if it produced steel thinking *only* of its private production costs (MCp) and comparing this with the price at which it will sell its steel (D=P=MPB=MSB), will produce **Qc** of steel, where MCp = Pc. This is the profit maximising output of the steel firm. If the firm produced more than **Qc** then the marginal cost of making steel would be higher than the price at which it sold, and the firm would lose profits. If it produced less then the marginal cost of making steel would be below the selling price and the firm could increase its profits. Only at **Qo** can it not increase profits by changing output. However, this output of steel is *not* the socially optimal quantity since the steel firm is failing to take into account the external costs of making steel – which is the lost output of fish due to the pollution of the lake, which reduces the profits of the fishery. The money value of this damage to the fishery is represented by the vertical distance MCE, which is the Marginal External Cost of producing steel. The total Marginal Social Cost of producing steel is the marginal private cost to the firm (MCp) plus the external cost to the fishery (MCE); i.e. MSC = MCp + MCE. This MSC of producing steel is represented by the upper line MSC. Social welfare is maximised where the addition to social benefit of the last unit of steel produced is equal to the marginal social cost, and this occurs at output **Qo**. Viewed from the perspective of society, the steel firm is making too much steel since, by producing beyond **Qo**, MSC>MSB. There is a net welfare loss at **Qc** of **abc**. One way to secure the optimum output of **Qo** is, as we have seen, to impose a unit tax on the steel firm equal to the extent of the MEC. This raises the steel firm's cost curve to MSC and causes it to select output **Qo** as its profit maximising output.

The same result can, however, be achieved by ascribing a property right in the lake to either the steel firm or the fishery – as *per* the Coase Theorem. Suppose the lake is owned by the steel firm. It might be thought that the steel firm could then pollute to its heart's content, but this is not the case. Consider if the steel firm produces **Qc** of steel as if the external costs to the fishery were of no account. The increase in the steel firm's profits by producing **Qc** rather than the social optimal **Qo** is the triangle **acd** (since P > MCp until **Qc**). However, the cost to the fishery of this extra output is MEC x (Qc-Qo), which is the area **abcd**. By producing beyond the social welfare maximising output **Qo** the steel firm is adding more to the costs of the fishery than it is adding to its own profits: that is, **abcd > acd**. It follows that the fishery could pay the steel firm to cut its output to **Qc** since the sum of money the steel firm would require to cover its lost profits (**acd**) is *less than* the reduction in costs the fishery would enjoy (**abcd**). The steel firm would be left no worse off, but the fishery would gain the area **abc**. *In other words, the gain to the fishery in increased profits from less pollution exceeds the loss of steel firm profits, and the fishery can afford to compensate the steel firm and still be better off.* Reducing steel output from **Qc** to **Qo** therefore represents a Pareto improvement, and the outcome is that **Qo** quantity of steel is produced – which is the socially optimal quantity where MSC = MSB. Thus, by allocating a property right the system of free exchange yields the optimum quantity of output and negative externalities *without* the need for a tax.

Imagine, instead, that the property right in the lake is accorded to the fishing company. Will the fishing company allow the steel firm to pollute the lake? Yes – provided the payments it receives from the steel company for the permission to do so exceeds the profits it would have made from not allowing it to do so. In this case, then, the steel firm must pay the fishery for the right to dump pollution in the lake. Starting from zero output of steel, it can be seen that the profit the steel firm receives from producing more steel (P – MCp) exceeds the loss of profit the fisher incurs – which is MCE. The steel firm can therefore afford to compensate the fishery for its marginal loss (MCE) and still make a net profit. Hence it will do so. Suppose we arrive at output **Qs**. Will the steel firm want to increase output to **Qo**? Yes. By increasing output from **Qs** to **Qo** the steel firm will add **fade** to its profits. This additional profit is sufficiently large for the steel firm to be able to compensate the fishery for the losses caused by the extra pollution (which is the amount **gade**) and still be better off. Again, this is a Pareto improvement: the steel firm has gained and the fishery is no worse off. Thus, output will increase to **Qo**, which is the socially efficient output. At this point no further increases in steel output will occur since the extra profit to the steel firm from producing beyond **Qo** is *less than* the cost this extra output imposes on the fishery. The steel firm can no longer compensate the fishery for lost profits and be better off and hence no further production will occur. Once again, then, the socially efficient output of steel and pollution will occur *without* the need of government intervention.

Thus, it makes no difference to the production outcome whether the property right to the lake is awarded to the fishery or the steel company. In either case, the social welfare maximising output where MSC = MSB is arrived at. It does, however, make a difference to the firms since, as in the case of the piano playing neighbour, there is an *endowment effect*. When the property right was given to the steel firm the fishery had to transfer wealth to the steel company out of its profits – economic rent was shifted from the fishery to the steel firm. And when the property right was awarded to the fishery, the steel firm had to transfer wealth to the fishery to be allowed to increase output. These are transfers between the parties; from a social point of view they do not matter – what matters is that the social welfare maximising output is arrived at.

Production Externalities: A Formal Analysis

Let us now express our results for the production externality steel/fishery example in more formal terms.[1]

Firm S produces steel, s, and pollution, x, which is dumped freely in a lake. Firm F, a fishery, is negatively impacted upon by firm S's pollution.

The steel firm's cost function is:

$$C_s(s, x) \qquad (3)$$

Where s is the quantity of steel produced and x is the attendant level of pollution. We assume that an increase in output of steel (s) *increases* the total (private) costs of the steel firm (dCs/ds > 0), but an increase in pollution (x) *decreases* the firm's costs, since limiting pollution costs money (filtering pollutants out of waste products, using more expensive bio fuel etc). It is cheaper to pollute than not pollute. Thus:

$$\frac{dCs}{dx} < 0$$

This shows that a small increase in pollution generates a small reduction in the cost of producing steel.

The cost function of the fishery is:

$$C_f(f, x) \qquad (4)$$

Where f is the cost of producing fish (feed, nets etc) and x is the amount of pollution generated by the steel firm. Again dCf/df > 0, but the pollution of the steel firm *increases* the costs of producing fish since the fish die or become sick; thus:

$$\frac{dCf}{dx} > 0$$

The problem of negative externalities is here brought sharply into focus: the steel firm benefits from creating pollution, but this same pollution damages the fish farm; and, of course, the fishery's costs do not depend only on its output – they depend also on the steel firm's output (and hence pollution).

The steel firm is assumed to want to maximise profit, where profit is TR – TC. Thus the steel firm's profit maximisation problem is:

[1] For this analysis I have used H. Varian, *Intermediate Microeconomics* (Norton and Company, New York, Ninth Edition, 2014), pp. 669-672.

$\mathbf{Max\ PsS - Cs(s, x)}$ with respect to s and x. (5)

The fishery's profit maximisation problem is:

$\mathbf{Max\ Pff - Cf(f, x)}$ with respect to f (since the fishery does not control x). (6)

Note that the steel firm *chooses* its own pollution level x, which is then set for the fishery.

If we assume perfect competition in both markets, so price is given to each firm and fixed, then each firm will maximise profit when the marginal cost of producing the last unit is equal to its price. For the steel firm there is a marginal cost and price for its steel, but, since there is no market for pollution (which is just dumped for free in the lake) there is no price for pollution. Hence the firm's profit maximising conditions are:

$$\mathrm{Ps} = \frac{\partial \mathrm{Cs}}{\partial S} \qquad (7)$$

$$\mathrm{Px} = 0 = \frac{\partial \mathrm{Cs}}{\partial \mathrm{x}} \qquad (8)$$

(8) means that the firm will keep polluting until the reduction in its costs from an extra unit of pollution is zero.

The fishery's profit maximising condition is:

$$\mathrm{Pf} = \frac{\partial \mathrm{Cf(f,x)}}{\partial \mathrm{f}} \qquad (9)$$

So the fishery will keep producing fish until the marginal cost of the last fish produced equals the price at which it will sell.

The point, again, is that the pollution imposes a marginal cost on the fishery but does not do so for the firm that produces the pollution – indeed, for the steel firm, pollution *reduces* its marginal costs. Pollution is good for the steel firm but bad for the fishery and the cost of pollution only affects the profit maximising output of fish. This increased cost to the fishery from pollution is the *external cost* of making steel and adds to the *Total Social Cost of producing steel*, where the MSC of steel making is the marginal private cost of the steel firm plus the marginal external cost (MEC) imposed on the fishery (MSC = MPC + MEC). This external cost is being ignored by the steel firm and it will produce too much steel from the viewpoint of society as a whole. It is not allocatively efficient, since Ps < MSC.

The externality problem arises here because the steel firm has a zero price for an output it produces – namely pollution. Yet the fishery company would be prepared to pay the steel firm *not* to produce. Pollution actually commands a *negative* price.

We can now apply Coaseian analysis to this situation. Imagine that the fishing company has a property right to the lake. It could then *sell* to the steel company the right to offload pollution into its waters. Let q be the price per unit of pollution and x the quantity of pollution. In this case, the steel firm (which now has to pay to pollute) has the following profit-maximising problem:

Max PsS − qx − Cs(s, x) with respect to s and x. (10)

While the fishing company's profit maximising problem is:

Max Pff + qx − Cf(f, x) with respect to f and x. (11)

Putting a price on pollution has two effects. Pollution is now a negative component in the steel firm's cost function as it has to pay the fishery to pollute, causing pollution to be a cost to the firm. And pollution is now a positive term for the fishery as it receives money from the pollution. The profit-maximising conditions are as follows:

$\mathrm{Ps} = \frac{\partial \mathrm{Cs(S,X)}}{\partial \mathrm{S}}$ (12) price of steel = marginal cost of making steel

$\mathrm{q} = -\frac{\partial Cs(S,X)}{\partial X}$ (13) price of pollution = reduction in cost from increasing pollution

$\mathrm{Pf} = \frac{\partial \mathrm{Cf(f,X)}}{\partial \mathrm{f}}$ (14) price of fish = marginal cost of producing fish

$\mathrm{q} = \frac{\partial \mathrm{Cf(f,X)}}{\partial \mathrm{X}}$ (15) price of pollution = marginal cost of pollution to fishing firm

Because pollution now has a price for both firms they adjust their behaviour accordingly. The steel firm stops polluting when the reduction to its own costs from polluting is equal to the price it must pay to the fishery to pollute. And the fishery sells to the right to pollute until the price it receives from the last unit of pollution sold is equal to the extra cost it incurs to its fish from the pollution. In doing so, they arrive [from (13) and (15)] at the socially optimal quantity of pollution:

$$-\frac{\partial \mathrm{Cs(S,X)}}{\partial \mathrm{X}} = \frac{\partial \mathrm{Cf(f,X)}}{\partial \mathrm{X}} \qquad (16)$$

This condition states that the fall in the marginal cost of steel production due to pollution is equal to the marginal cost to the fishery of pollution. If this condition is arrived at, the quantity of pollution is optimal. If the fall in costs to the steel firm from an extra unit of pollution were greater than the increase in costs to the fishery of that pollution then it would be efficient to produce more pollution; and if the reduction in costs due to pollution to the steel firm were less than the increase in costs to the fishery caused by that pollution, then too much pollution is created. The optimal amount is when the marginal benefit of pollution to the steel firm is equal to the marginal cost to the fishery of pollution and this is attained when (10) is satisfied – as it will be in this case.

We get, as Coase predicts, the same result if the steel firm owns the lake and the fishery has to pay to cause it to reduce pollution. Again, q is the price of pollution and x is the quantity of pollution.

The steel firm's profit equation is:

$$\Pi s = Pss - qx - Cs(s, x) \qquad (17)$$

Note the negative term -qx indicates that, if the steel firm produces a unit of pollution, this now represents a *cost* to the steel firm as this will be one unit of pollution-reduction the steel company can no longer sell to the fishery. There is, for the steel firm, an *opportunity cost* of polluting its own lake – namely the reduced payment it will receive from the fishery.

Differentiating by s and x and setting equal to zero (as the first-order condition for a maximum) we get:

$$\frac{\partial \pi s}{\partial s} = Ps - \frac{\partial Cs}{\partial s} = 0$$

$$Ps = \frac{\partial Cs}{\partial s} \qquad (18)$$

$$\frac{\partial \pi s}{\partial x} = -q - \frac{\partial Cs}{\partial x} = 0$$

$$q = -\frac{\partial Cs}{\partial x} \qquad (19)$$

This is the same result as (13) above. The steel firm will keep reducing costs by increasing pollution per unit until the reduction in the firm's private costs equals the amount the fishery would be prepared to pay (q) for the steel firm *not* to create one more unit of pollution. This will be the steel firm's profit maximising level of pollution. If q > $-\partial Cs/\partial x$ then the steel firm would make more money from the fishery by cutting its pollution than it would by increasing pollution and lowering its costs. It would therefore lower its pollution. Cutting pollution costs the steel firm money (e.g. it has to filter the waste product more rigorously) but it will receive more revenue from selling greater fishing entitlements to the fishery. As it cuts pollution, the marginal cost of cutting pollution increases (filtering has to become more and more rigorous) until eventually $q = -\partial Cs/\partial X$ and at this point the steel firm will stop reducing its pollution levels.

The fishery's profit function now that it has to pay q to the steel firm to reduce its pollution is:

$$\Pi f = Pff - qx - Cf(f, x) \qquad (20)$$

Differentiating to set equal to zero and maximise profit we get:

$$\frac{\partial \pi f}{\partial f} = Pf - \frac{\partial Cf}{\partial f} = 0 \qquad (21)$$

$$Pf = \frac{\partial Cf}{\partial f} \qquad (22)$$

$$\frac{\partial \pi f}{\partial X} = -q - \frac{\partial Cf}{\partial X} = 0 \qquad (23)$$

$$q = -\frac{\partial Cf}{\partial X} \qquad (24)$$

This means that the fish farm will pay q to reduce the steel firm's pollution by successive units until the cost of a unit reduction in pollution (q) is equal to the reduction in costs it will enjoy from the reduced pollution. If the price of reducing pollution (q) is less than the reduction in costs it receives, then the firm will continue to pay the steel firm to cut its pollution. And if the price of a unit reduction in pollution exceeds the reduction in fishing costs, then the firm will not pay. Hence the profit maximising level of pollution from the fishery's perspective is when the two are equal.

Combining (19) and (24) we arrive at the equilibrium condition:

$$\frac{\partial Cs}{\partial X} = \frac{\partial Cf}{\partial X} \qquad (25)$$

This states that the marginal benefit of pollution to the steel firm is equal to the marginal cost of pollution to the fishery – which is the social welfare maximising outcome we arrived at in (16).

This analysis confirms that, in the case of production externalities, the socially optimal pattern of production (in this case between fishing and steel making) is arrived at whatever the distribution of property rights. All that is required is that property rights in a resource *are* allocated and that there are no transaction costs involved in the bargaining process.[1]

The Practical Applicability of the Coase Theorem

The Coase Theorem suggests that a free market economy with allocated property rights to all resources would tend to produce an optimal allocation of resources even when negative production or consumption externalities exist. In which case, a crucial argument in favour of state intervention in markets to correct market failure would seem to have been neutralised. No wonder the theorem was so eagerly welcomed by the free-market economists of Chicago like Friedman and Stigler when they were first encountered it! Yet, there would seem to be no end of governments still intervening to correct the output of polluting firms and consumers. Why is this? The reason is that to go beyond the theory of the Coase's argument to its actual application is exceedingly complicated. As we observed, the theory assumed that there are no transaction costs. Only then can an optimum allocation of resources be arrived at by bargaining between the affected parties. Once it is recognised that bargaining is costly

[1] *Ibid*., p. 677.

in time and resources, then it will frequently not be economically worthwhile for parties to engage in a market solution to their externalities problem. This is most apparent when numerous parties are involved. Imagine a polluting car driving down a street: even if we give local residents a property right in clean air, it would be infeasible for a driver to compensate each affected party as they drove down the street. The same applies to a factory polluting the air. There might be thousands of affected parties over an area of many miles. Even if all the affected persons could be identified, it would be impossible for them all to be compensated. It is more plausible that the affected persons could pay the factory not to produce. Here the main problem is *free-riding*: if I am one of many hundreds of people affected by the pollution it would be rational for me to hold out from paying to have the pollution reduced, hoping that if others pay then I will benefit from less pollution for no cost. When fewer people are involved – like our initial example of the doctor and the sweet-maker – then there is a likelihood of strategic behaviour, with one party pushing for high terms before accepting, in the hope of annexing most of the gains. If the other party refuses to negotiate then the process can break down. Veljanovski cites the case of *Bradford v. Pickles* in 1895. Pickles was a farmer through whose land a stream ran which supplied the town of Bradford with water. Pickles claimed a property right in the stream and demanded that Bradford Corporation pay him not to block it. Although the courts found in his favour, Bradford Corporation accused him of blackmail and refused to pay anything and when Pickles went ahead a blocked the stream he damaged his own farm and went bankrupt![1]

Yet this does not mean that the Coase Theorem is devoid of practical application. In a 2021 article, 'Environmental Applications of the Coase Theorem', Deryugina, Moore, and Tol survey examples of applications of the Coase to actual environmental problems where the outcomes arrived at were within the spirit of Coase's argument.[2] For instance, several firms whose activities are associated with significant pollution hazards have removed the risk of legal action by neighbours by buying them out. In 2002 the American Electric Power Company of Ohio purchased 90 properties from 221 local residents after health concerns were linked to the plant. These home-owners were paid above-market values for their properties, indicating that they were being compensated for potential exposure to the plant. In other words, it was possible for American Electric Power to buy-out neighbouring residents and still make a profit – an example of a Coaseian solution. Other firms have acted similarly. Dow Chemicals, for example, bought out the residents of the town of Morrisonville in Louisiana in 1993 after chemicals spilt into the town's drinking water. The town is now abandoned. Schiphol Airport, near Amsterdam in the Netherlands, has compensated local homeowners and paid for noise-reducing insulation in return for being allowed to run more flights. In like manner, the government of Berlin compensates residents near

[1] Veljanovski, *Economic Principles of Law*, p. 49.
[2] T. Deryugina, F. Moore, and R. Tol, 'Environmental Applications of the Coase Theorem', *Environmental Science and Policy*, 120 (2021), pp. 81-88.

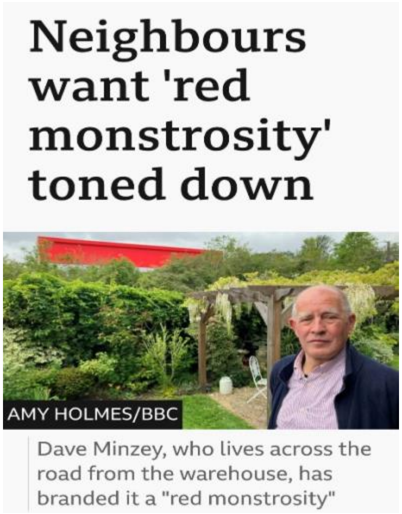
Tegel Airport. The Royal Norwegian Airforce bought up houses located near its Orland base and pays for insulation.

In all these cases the producer of the externality paid the compensation – which is more likely, partly because legal systems usually favour the victim of a nuisance over its originator, and partly because there tends to be one polluter and many victims of pollution, so it is easier for the polluter to initiate a settlement than for the many victims to coordinate to pay a polluter *not* to produce. However, there are examples of the victims of a negative externality paying to have its quantity reduced. In 2016 apartment owners in New York joined together to pay a local property developer $11 million *not* to build up in such a way as to restrict their views. Mark Zuckerberg spent $43.8 million buying out his neighbours in Palo Alto to ensure his security and privacy. When Vittel, a mineral water producer, found its fresh water being compromised by pollutant run-off from local farms, it responded by buying-out some farms completely and paying other farmers to keep their use of nitrogen within specified limits. These actions can also cross international boundaries: concerned about sulphur pollution emanating from Chinese factories, the Japanese government provided $300 million to China to pay for pollution-reduction technology. When more than two parties are involved – as in this case – difficulties in coordinating compensation payments among the victims to pay for mitigation means that it generally requires the state to step in to facilitate the bargain. The City Council in Santa Maria in California went one step further: to prevent free riding, it imposed a tax on all residents near a feedlot that was generating offensive smells and used the money to pay the operator to shut down. Deryugina, Moore, and Tol sum up as follows:

> For many environmental problems, harms are diffused over many people, so that negotiating individual contracts to reach the Pareto optimum would be impractical and costly. In practice, our review reveals that most substantive applications of Coase-like bargaining involve an entity acting on behalf of the aggregated interests of a large population, substantially reducing the transaction costs involved and solving the coordination problem between agents. These entities fall into two main categories—governments acting as agents of their people … and environmental groups acting on behalf of their members.[1]

Such examples show that the Coase Theorem is not simply a theoretical curiosity. The logic is clear: when there are two rival claimants to a resource, the claimant whose use commands a higher net-return after costs will prevail since they can make good the other party and still make a profit. Such situations are extremely widespread: scan through any newsfeed and one is sure to encounter numerous examples. Here are a couple of recent examples.

[1] *Ibid*., p. 87.



It is easy to see the applicability of Coaseian solutions to these problems. It is hard to think that Mick Jagger and Eric Clapton could not, between then, have mobilised the payment necessary to preserve their valued vista. That in these and similar cases the plaintiffs have recourse to courts and planning injunctions takes us back to the beginning of our story in Wigmore and Wimpole Streets. Three factors seem to explain why Coase-inspired solutions are not more frequently seen. First, the problems of transaction costs and strategic bargaining, which mean that while, in theory, a free market with extensive property rights could resolve externality conflicts in a social-welfare maximising way, in reality the complexity and cost of applying this method of resolution preclude its application. Second, the endowment effects mean that when a polluter is a company and the victims private individuals, there is a widespread sense that for the latter to pay the former *not* to pollute is iniquitous and there is a preference to use government to intervene on behalf of the many over the few. Third, the common-law tradition has been that one should not inflict a nuisance on one's neighbours and that in cases of contested rights it is the originator of the nuisance who should be liable for the damage and should be made to desist. Anyone familiar with the doorway to the clock tower in St Albans will need little reminder of this fact.