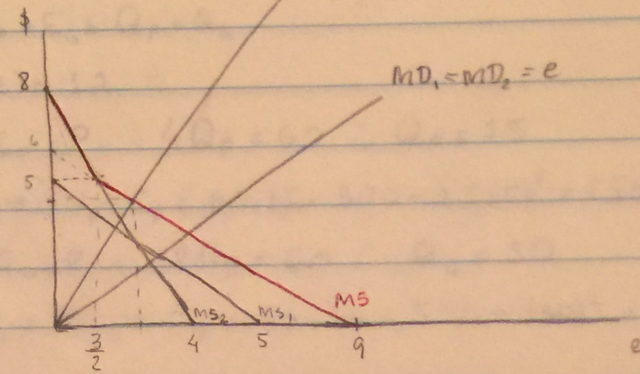
① $MS_1 = 5 - e$ $\qquad MD_1 = MD_2 = e$

$MS_2 = 8 - 2e$

a)+b)



$e_1 = 5 - MS$ $\qquad e = e_1 + e_2 = 5 - MS + \frac{8 - MS}{2} = \frac{18 - 3MS}{2}$

$e_2 = \frac{8 - MS}{2}$ $\qquad e = 9 - \frac{3}{2} MS$

$MS = \frac{18 - 2e}{3} \therefore MS = \begin{cases} 6 - \frac{2}{3}e & e \in [3/2, 9] \\ 8 - 2e & e \in [0, 3/2) \end{cases}$

$MD_1 = e \;,\; MD_2 = e \qquad MD = MD_1 + MD_2 = 2e$

c) t^*: $MD = MS$

$6 - \frac{2}{3}e = 2e \therefore 6 = 2e + \frac{2}{3}e \therefore 6 = \frac{(6+2)e}{3} \therefore 18 = 8e \therefore e^* = 2.25$

$MD = t^* = 2(2.25) = 4.5$

Firm 1's emissions:

$5 - e_1 = 4.5 \therefore e_1^* = 0.5$

Firm 2's emissions:

$8 - 2e_2 = 4.5 \therefore e_2^* = \frac{3.5}{2} = 1.75$

(4) $P = 60$

$E = Q$

$C_F = 300 + 2Q_F^2$ $MC_F = 4Q_F$

$C_G = 500 + Q_G^2$ $MC_G = 2Q_G$

$E = E_F + E_G = Q_F + Q_G$

$MD(E) = 12$

a) $MC_F = P$: $4Q_F = 60 \therefore Q_F = 15$

$\Pi_F = PQ_F - C_F = 60 \times 15 - 300 - 2(15)^2 = 150$

$MC_G = P$: $2Q_G = 60 \therefore Q_G = 30$

$\Pi_G = PQ_G - C_G = 60 \times 30 - 500 - (30)^2 = 400$

b) Pigouvian tax $= t^* = MD(E) = \$12/E = \$12/Q$

$MC_F = 4Q_F + 12$ $C_F = 300 + 2Q_F^2 + 12Q_F$

$MC_G = 2Q_G + 12$ $C_G = 500 + Q_G^2 + 12Q_G$

$MC_F = P$: $4Q_F + 12 = 60 \therefore Q_F = 12$

$\Pi_F = PQ_F - C_F = 60(12) - 300 - 2(12)^2 - 12(12)$

$= 720 - 300 - 288 - 144 = -12$

$MC_G = P$: $2Q_G + 12 = 60 \therefore Q_G = 24$

$\Pi_G = PQ_G - C_G = 60(24) - 500 - (24)^2 - 12(24)$

$= 1440 - 500 - 576 - 288 = 76$

c) Subsidy $= s^* = MD(E) = \$12/E = \$12/Q$

$C_F = 300 + 2Q_F^2 - 12(15 - Q_F)$; $MC_F = 4Q_F + 12$

$C_G = 500 + Q_G^2 - 12(30 - Q_G)$; $MC_G = 2Q_G + 12$

$MC_F = P \Rightarrow Q_F = 12$

$\Pi_F = PQ_F - C_F = 60(12) - 300 - 2(12)^2 + 12(15) - 12(12)$

$= 720 - 300 - 288 + 180 - 144 = 168$

$MC_G = P \Rightarrow Q_G = 24$

$\Pi_G = PQ_G - C_G = 60(24) - 500 - (24)^2 + 12(30) - 12(24)$

$= 1440 - 500 - 576 + 360 - 288 = 436$

(5) $C = Q^2$ $MC = 2Q$

$E = 2Q$ $MD = \$2$ $t^* = \$2$ $P = \$10$

$C = Q^2 + 2E = Q^2 + 2(2Q) = Q^2 + 4Q$ $TD = 2E = 4Q$, $MD = 4$

$MC + MD = 2Q + 4$

a) $P = MC + MD$

$10 = 2Q + 4 \therefore Q = 3$

$\pi = PQ - C - t^*E = 10(3) - 3^2 - 2(2 \times 3) = 9$

$t^*E = 2(2 \times 3) = 12$

b) $E = Q$

w/o device $\pi = 9$

w/device $TD = 2E = 2Q$ $MD = 2$

$P = MC + MD \therefore 10 = 2Q + 2 \therefore Q = 4$

$\pi^D = PQ - C - t^*E = 10(4) - 4^2 - 2(4) = 16$

WTP $\pi^D - \pi = 16 - 9 = 7$

c) WTP = 0 ; gov. regulation creates demand for pollution abatement equipment.

2. a. The efficient outcome is where the fishery is located downstream of the mill and the treatment plant is built. This results in a total joint profit of $800.

b. The four outcomes are tabulated below.

	Right to pollute		Right to clean	
	Mill	Fishery	Mill	Fishery
Fishery upstream	$500	$200	$300	$300
Fishery downstream	$500	$100	$300	$500

c. The no-bargain solution in the case where the Mill has the right to pollute is the upper-right cell in the payoff matrix ($500 $200). With costless bargaining, the Fishery could offer to purchase the equipment for the Mill. The efficient outcome will then result since the increase in profit to the Fishery where the pollution control is installed (and they move downstream) is $300, which is greater than the $200 needed to cover the costs of the equipment for the Mill.

3. The text argues that the relevant concepts of market failure related to pollution (it is a *public bad* or it produces an *externality*) are logically redundant. Furthermore, it has established that in the absence of market failure, pollution would be allocated efficiently as goods and bads are in well-functioning markets. In the words of chapter 5, pollution levels would be "Pareto irrelevant" if these market failures did not exist. The validity of the statement therefore hinges on the extent to which the market failures associated with pollution arise from issues of property rights.

Why are there no markets that arise to optimally price and allocate pollution? Economists would tend to agree that the *proximate* cause for the market failure is the absence of clearly defined and/or enforceable property rights. In this sense, the statement in the question is quite true. The very important omission of this statement is regarding the *ultimate* cause of market failure. There are very fundamental reasons why property rights are defined and enforced for some goods and bads and not others. In the case of non-point source pollution, the characteristics of non-rivalry and nonexcludability are fundamental to the bad and these characteristics limit the capacity of government to define and enforce property rights and resolve disputes. It is for this reason that a stronger statement that pollution problems are *merely* a failure of government to define and enforce property rights is a bit simplistic.

4. a. The number of shoes and baked goodies the merged firm makes when $P_S = 8$ is 2 and 4, respectively, while the number of shoes and baked goodies the merged firm makes when $P_S = 14$ is 6 and 2, respectively.

We can solve the maximization problem for the combined firm by first merging the two cost functions to make a combined Cost Function. Then take the derivative of the combined cost function with respect to baked goods and shoes to get

7. a. The centralized decision making within a company should make transactions costs lowest for internal trades. Considerations of compensation, presumably the primary topic of negotiations, are absent when the same firm observes all the costs and benefits of a trade.

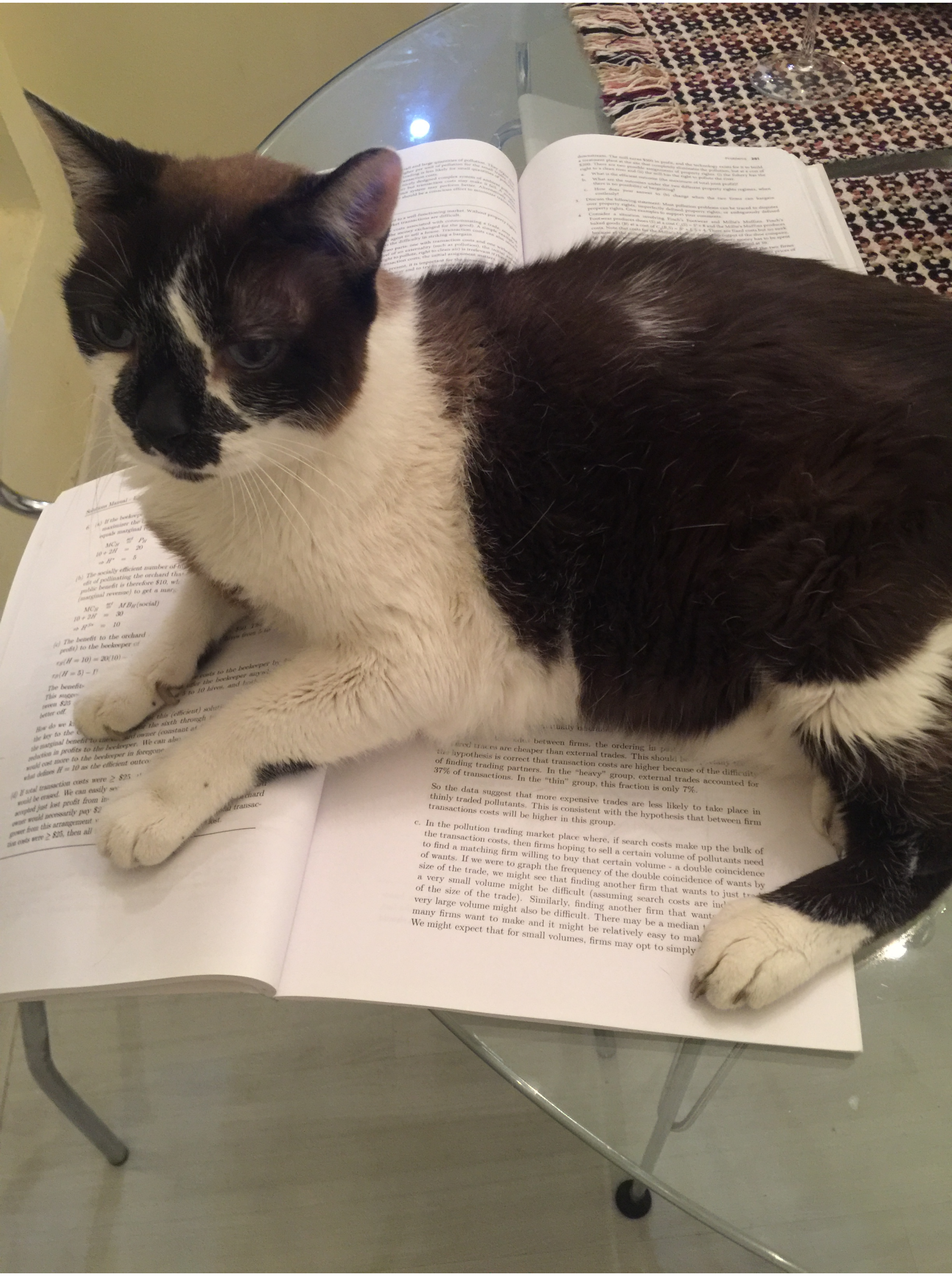
   The *existence* of brokered transactions is strong evidence that those transactions have lower overall transaction costs than unbrokered external trades. If simply finding someone with whom to trade is a problem, an intermediary who specialized in arranging trades could be very efficient. So, from lowest transaction costs to highest, we would expect the order to be: internal, brokered, external.

   b. There is some evidence in the data that support the hypothesis in a. Since the question claims that low trading volume indicates higher transaction costs we cannot tautologically conclude that there must me higher transaction costs since there are low numbers of trades. But there may be some information in the relative composition of the trading data. Consider the pollutants with the fewest number of total trades: CO, PM, and SO_X. These pollutants saw 12 internal trades, 13 brokered trades, and only 2 external trades. Compare this to the more heavily traded pollutants: NO_X and VOC. These saw 36 internal trades, 76 brokered trades, and 65 external trades. Internal trades may be cheap, but their number is limited by the size of firms and the allocation of pollution within firms. This accounts for internal trades making up only 20% of transactions in the "heavily traded" pollutants. Internal trades, in contrast, make up 44% of transactions in "thinly traded" pollutants. Higher transactions costs for thinly traded pollutants suggests that external and brokered trades are frequently too difficult to arrange, even when they would be mutually desirable.

   With respect to trades between firms, the ordering in part (a) suggested that brokered trades are cheaper than external trades. This should be especially true if the hypothesis is correct that transaction costs are higher because of the difficulty of finding trading partners. In the "heavy" group, external trades accounted for 37% of transactions. In the "thin" group, this fraction is only 7%.

   So the data suggest that more expensive trades are less likely to take place in thinly traded pollutants. This is consistent with the hypothesis that between firm transactions costs will be higher in this group.

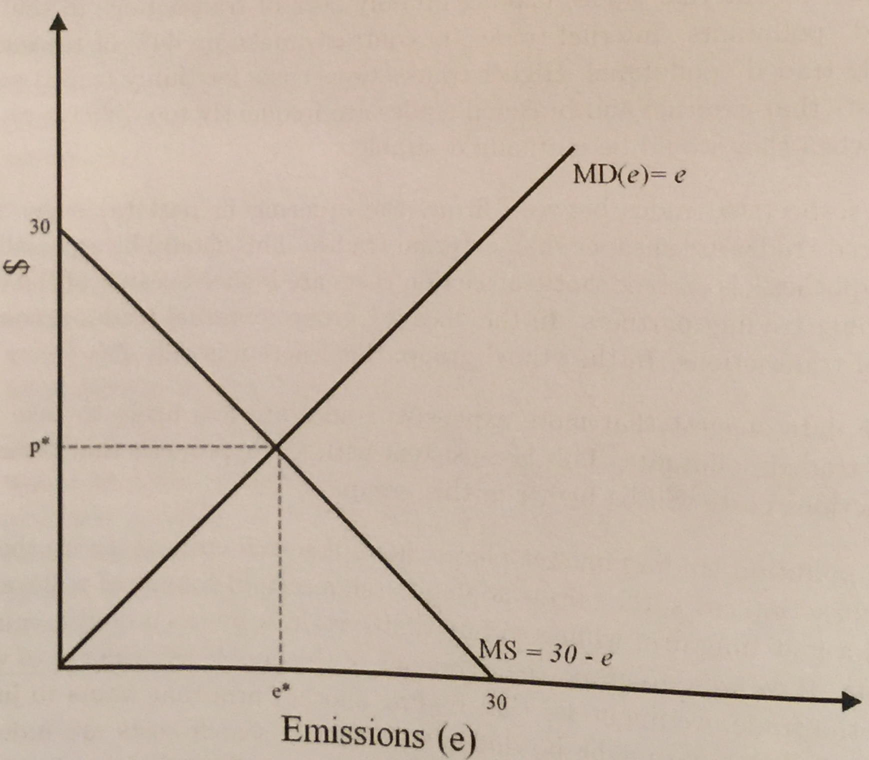
   c. In the pollution trading market place where, if search costs make up the bulk of the transaction costs, then firms hoping to sell a certain volume of pollutants need to find a matching firm willing to buy that certain volume - a double coincidence of wants. If we were to graph the frequency of the double coincidence of wants by size of the trade, we might see that finding another firm that wants to just trade a very small volume might be difficult (assuming search costs are independent of the size of the trade). Similarly, finding another firm that wants to trade a very large volume might also be difficult. There may be a median trade size that many firms want to make and it might be relatively easy to make these trades. We might expect that for small volumes, firms may opt to simply internally trade


between firms, the ordering in
traces are cheaper than external trades. This should
hypothesis is correct that transaction costs are higher because of the
of finding trading partners. In the "heavy" group, external trades accounted for
37% of transactions. In the "thin" group, this fraction is only 7%.
So the data suggest that more expensive trades are less likely to take place in
thinly traded pollutants. This is consistent with the hypothesis that between firm
transactions costs will be higher in this group.
c. In the pollution trading market place where, if search costs make up the bulk of
the transaction costs, then firms hoping to sell a certain volume of pollutants need
to find a matching firm willing to buy that certain volume - a double coincidence
of wants. If we were to graph the frequency of the double coincidence of wants by
size of the trade, we might see that finding another firm that wants to just
a very small volume might be difficult (assuming search costs are
of the size of the trade). Similarly, finding another firm that
very large volume might also be difficult. There may be a median
many firms want to make and it might be relatively easy to
We might expect that for small volumes, firms may opt to

and thus avoid brokering fees on such a small trade or the relatively high search cost of finding another firm that wants just a small trade. We also might expect that a firm wanting to trade a large volume might look to a broker to make a trading match, being unable or unwilling to internally trade a large volume and unwilling to commit to the search costs of finding another firm looking to make a large trade. This is just one scenario, but generally we might think that it is more likely that small volume trades will occur internally.

8. The "offset system" is tantamount to a marketable permit system. First, existing firms are given the de facto property right to emit pollution just as firms are given permits, or the right to emit pollution, in the marketable permit system. Second, new firms must convince, or in other words compensate, existing firms to reduce pollution so that they may have the right to emit pollution on a one-for-one basis - just the same as a firm in the marketable permit system must pay another firm on a one-for-one basis for permits if it wants to emit more pollution. So in both cases, property rights are assigned, quantity is capped, and trading is allowed to take place.

9. a. The efficient, or first-best, solution is achieved when pollution tax is set at $15. This results in the optimal level of 15 tons of pollution abatement as shown in the figure below.



b. Given the information that indicates we are in a second-best world, we know that every ton of emissions reduced results in $10 of welfare loss (due to the fact that pre-existing taxes are distortionary) the marginal damage of emissions should