Externalities from Concentrated Animal Feeding Operations

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Classical economics is based upon three assumptions about the firms and individuals that participate in the market: they are goal-oriented, meaning that they are interested in fulfilling their own personal or private goals; they are rational, meaning that their behavior is the result of privately considered costs and benefits; and they must deal with scarce resources, meaning that there is not enough time, resources, or money to fulfill all of their wants and needs. That is, when individuals and firms operate and make decisions, they do so in a way that maximizes their personal utility given the constraints and limitations associated with finite resources.

However, not all decision making can be viewed in isolation for each individual or firm. In many cases, decisions affect others. Instances such as these fall under the category of market failures, which are instances where the perfectly competitive market fails to produce a Pareto optimal amount or equilibrium. These can occur in exchange or production when a non-optimal allocation of scarce resources takes place. For example, the decision to donate blood has the benefit of potentially saving the life of three other people, in addition to securing access to possible future blood transfusions to the donor and his/her family. On the other hand, the decision to build an airport near a busy subdivision may result in noise pollution that damages the residents nearby. These benefits and costs that affect individuals other than the decision maker—these external effects—have been termed *externalities* and can be either positive or negative. Positive externalities produce a benefit to a party other than the decision maker, whereas negative externalities harm an otherwise uninvolved party (Browning and Zupan 2009). There are many applications of the theory of externalities in the economics literature of today; one such example examines the consequences of industrial agriculture, namely livestock production in concentrated animal feeding operations (CAFOs).

EXTERNALITIES

E.J. Mishan (1971) describes the characteristics of externalities. These include discrepancies between private and social net products. Externalities arise when perfect competition does not result in optimality. Furthermore, "the effected produced is not a deliberate creation but an *unintended* or *incidental* by-product of some otherwise legitimate activity" (Mishan 1971, 2).

Mishan then describes the history of the development of the theory behind externalities. He specifically mentions Pigou, whose study focused on the inequality between marginal benefit and marginal cost, Knight, who was most concerned with the exploitation/undervaluation of scarce natural resources, and Viner, whose work focused on the differences between pecuniary and technological externalities.

Mishan then applies this background information to economic situations surrounding public goods and actions, such as pollution. He distinguishes between public goods and private goods in that public goods can be based on benefits or costs conferred that cannot be assigned to a specific person/entity. Some goods, such as highways, may function more like public goods in the long run than in the short run. The marginal costs and benefits once the highway is built cannot be restricted to any one driver. Additionally, how "public" a public good is depends on economies of scale—leading to lower long run average costs, travel costs, and the number of people or amount of usage the good has. That is, to use the highway example, the more people that have access to, utilize, and gain (or lose) utility the highway, the more "public" is the highway, which can lead to economic externalities.

Then Mishan suggests policies to internalize or address externalities. Excise taxes and subsidies can be used to correct externalities by government intervention. Another example of government intervention that Mishan mentions but quickly dismisses as both inefficient and impractical is a ban on the externality. He also discusses the Coase Theorem, which in the absence of an income effect, shows how property rights can compel an actor to want to protect a public good. Differences in the optimal amount of correction of externalities depend upon the private equilibrium conditions before the externality is internalized. As described by Mishan, if the damaged party must pay an industry to decrease the amount of pollution, the equilibrium amount of pollution will be higher than if the company has to pay the firms down river for the right to pollute the river; that is, the willingness to pay for corrected externalities is less than the willingness to accept damages from externalities[1].

Mishan also presents issues of distribution, equity, and protection of the environment for posterity within the context of pollution externalities as well. For instance, externalities such as pollution are more likely to harm poorer members of society, as they lack the resources to effectively fight against spillover effects occurring closer to their neighborhoods. In other words, wealthier individuals and firms can more easily compensate polluting firms to get them to locate elsewhere. Additionally, if the firms receive property rights to pollute and thus operate under a willingness to pay scheme for the externality, they may have the incentive to over-pollute so that they are compensated to the level of pollution that they would otherwise want to produce. Issues of blame have also arisen, as situations where the firm causing the negative externality is seen as the “bad guy” for damaging uninvolved parties, even though either party receiving the property rights would lead to Pareto optimality (under Coase). Finally, Mishan discusses that information

[1] This is not universally accepted. The Coase Theorem states that in the absence of transactions costs, the same optimal amount of an externality will be produced regardless of who receives the property rights. As described by Dolbear in his 1967 paper *On the Theory of Optimum Externality*, the firm that receives the property rights experiences an income effect and can thus choose an amount of the externality outside of the firm’s initial budget constraints, implying that evaluations of the good/externality are not independent of the amount the individual possesses.

about the consequences of externalities such as pollution appears later, so that decisions made in the present may cause high levels of harm to future generations.

CONCENTRATED ANIMAL FEEDING OPERATIONS (CAFOS)

As defined by the United States Environmental Protection Agency (EPA), CAFOs are a specialized form of animal feeding operation (AFO). "AFOs are an agricultural operation where animals are kept and raised in confined situations. AFOs congregate animals, feed, manure and urine, dead animals, and production on a small land area. Feed is brought to the animals rather than the animals grazing or otherwise seeking feed in pastures, fields, or rangeland." The animals are also confined for at least 45 days in a 12-month period without grass or other vegetation in the confinement area during the normal growing season (EPA).

CAFOs are regulated by the EPA under the Clean Water Act (CWA) based on the number of animals that the facility has and the amount of pollution that the facility produces (Centner 2003). Designations include large, medium, and small CAFOs. Large CAFOs are required to partake in the National Pollutant Discharge Elimination System (NPDES), while medium and small CAFOs may or may not need permits. Though federally mandated, these permits are distributed and monitored by individual states. Thus, some states have more stringent regulations than others (Centner 2003).

The principle of economies of scale explains why this system of livestock production has developed. The concept of economies of scale is the condition that arises when a firm can increase output at a higher rate than its input costs increase. As livestock farms are able to raise more animals within the same amount of space, they can reap the benefits of increased output a very small change in costs because fixed costs remain constant. Not surprisingly, livestock production has become increasingly more concentrated. Over the last fifty years, the number of farms for various types of livestock has decreased dramatically. In 2003, there were 59 percent fewer cattle operations, 94 percent fewer dairy operations, and 95 percent fewer hog farms in the United States (Centner 2003).

This concentration of production has meant that the byproducts and other consequences of livestock production—such as manure/wastes causing pollution, the (over)use of antibiotics, and decreases in property values—are intensified. An especially problematic byproduct of the CAFO production process is the large amount of waste produced by the large number of livestock. Whereas livestock farms used to be able to use this manure as fertilizer, there are simply too many animals producing too much waste for all of it to be utilized. This excess waste must then be stored in lagoons or as a slurry in waste storage systems (Centner 2003); it can also be discharged into waterways depending on the regulation and size of the CAFO (Johnson et al. 1999). Though CAFOs are not allowed to directly release wastes into waterways (with exceptions for extreme weather events), there are no stipulations that specifically regulate runoff once the manure or wastewater is applied to cropland. Thus, these consequences are externalities because their impact extends beyond the CAFO to the community at large.

EXTERNALITES OF CAFOS: WATER POLLUTION

CAFOs are regulated under the CWA because they have an impact upon water systems. The large numbers of animals kept within the CAFO produce a vast amount of waste. Though there are nutrients—namely nitrogen and phosphate—in the manure that can fertilize the soil, there are so many wastes produced that they exceed the nutrient demand of the cropland (Kaplan et al. 2004). This means that many of these nutrients end up in the groundwater, which causes many environmental problems. In fact, as described by Chakravorty et al. (2007), CAFOs in two Arkansas counties generate as much waste as a city of eight million people. These wastes often make their way into groundwater, which is especially problematic since livestock wastes are not treated before storage in lagoons and/or application to land.

Nutrients from these wastes allow the primary producers in aquatic environments, such as algae and phytoplankton, to "bloom" or rapidly increase in population size. This process, called eutrophication, has dire environmental consequences. The algae and phytoplankton populations are so large that their predators cannot keep their populations in check, so many of these primary producers die and sink to the bottom of their aquatic environment. Once there, decomposers such as bacteria decompose these extra algae and phytoplankton. The decomposition process lessens the amount of dissolved oxygen (DO) in the water, which can cause fish kills, low species diversity and/or abundance, and dead zones in the water column where no organisms can live (Johnson et al. 1999).

Though eutrophication caused by CAFO manure has a large impact upon water quality and water pollution, it is not the only effect. For instance, though nitrogen is a major contributor to eutrophication, it has other effects as well. As described by Johnson, Wheeler, and Christensen (1999), problems arise when nitrogen converted from elemental form (N_2) to nitrate (NO_3^-) form. This can lead to drinking water contamination, which "impose[s] costs either by causing illnesses or increasing the costs of drinking water treatment" (1219). Manure also contains many pathogens, such as bacteria that can cause disease. Additionally, "pathogens (e.g., various bacteria, *Giardia*, or cryptosporidium) cause numerous illnesses, have been implicated in swimming restrictions, and can affect drinking-water supplies" (1219). These effects are clearly externalities because they impact individuals outside the firm/CAFO that decides, directly or indirectly, how much to pollute water via livestock production.

Studies have been conducted to determine the monetary value of marine environments that have been affected by eutrophication. One such study, conducted by Ahtiainen and Vanhatalo (2012), estimates the willingness to pay for improving water quality in areas where eutrophication was a problem. For their estimation, the cost of degradation is defined as “welfare forgone if the condition of the sea area follows the business-as-usual scenario and does not reach a good status (1). They use a Bayesian meta-regression, chosen because it is comprehensive, to estimate these degradation costs based on how much a person is willing to spend on the clean up/improved conditions. The natural log of willingness to pay is calculated as a function of a country’s gross domestic product (GDP) or the natural log of GDP, a water quality index (WQI) score, varying dimensions of the valuation scenario (The different versions of the questionnaire mention effects on recreation, biodiversity, et cetera), and the geographical area—local or distant.

The willingness-to-pay per person for improved marine environmental conditions ranged from $6 (for a small local change) to $235 (for a large change in a large area). This indicates that water pollution is important and costly. Since CAFOs are a major source of water pollution, there is need to address these externalities.

EXTERNALITIES OF CAFOS: AIR POLLUTION

Sneeringer (2010) examines how increasingly concentrated hog farms have impacted the areas in which they are located. In the South and the Midwest especially, air pollutants such as ammonia (NH_3) and hydrogen sulfide (H_2S, which then oxidizes into sulfur dioxide, SO_2) are especially worrisome. The EPA has thus become cognizant of the need to potentially regulate CAFOs under the Clean Air Act (CAA) as well as the CWA, but it lacks data about the effects on a national scale. Thus, in her article, Sneeringer "estimate[s] the effects of concentrated swine production and water-quality regulation of hog operations on ambient air pollution at the national level, using geographic changes in hog density and the variation in water-quality regulation in the United States between 1980 and 2002" (821).

Her empirical strategy thus examines the impact that hog production and water-quality regulation have upon air pollution. Her data measure ambient air quality (controlled for emissions, looking at NH_3 and SO_2), hog production (in hogs per square mile), water-quality regulation (an indicator if a state has water-discharge permits for hog operations), state-level odor and direct emissions regulations (a state's regulations about either the maximum concentration of odor allowed or regulations that require odor management plans), emissions from other sources (determined from the EPA's National Emissions Inventory) and other covariates (such as non-hog livestock production).

Her results suggest that there is a significant positive correlation between SO_2 and hog production, a significant positive correlation between water-quality regulations and particulate matter/NH_3 pollution in the presence of hog production, and a significant positive correlation between direct odor regulation and SO_2/NH_3 air pollution[2].

When the number of hogs in a county doubles, there is a 6.6 percent increase in sulfur-related air pollution. The effects are the worst in areas where hog production is most concentrated, due to the lagoon practices and subsequent over-application of manure as fertilizer.

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[2] Since most of the consequences occur with an increase in concentrated hog productions, Sneeringer tests for non-linearity and determines that a log-log functional form is most appropriate.

This is problematic because the areas that no longer have hog production had improvements in air pollution that were smaller than the damages to the areas that had increases in air pollution.

The more concentrated hog operations thus have the potential to undo air quality improvements brought on by the CAA. Sneeringer calculates that there is a per-hog externality of $31/hog, due to losses in property value, damage to human health, worsened conditions for growing crops, and decreases in worker productivity. She proposes that methods to reduce these air pollution externalities, such as biofilters, varying types of hog feed, landscaping techniques, and lagoon covers, are economically feasible and would impart a viable social benefit. For instance, lagoon covers would cost between $17-$33 per hog. Additionally, lagoon covers would likely decrease water pollution as well, further benefitting society.

Another form of air pollution arising from CAFOs is greenhouse gas emissions. As discussed by Fiala (2008), increases in meat production lead to higher levels of greenhouse gas (GHG) emissions, exacerbating global warming. As of the article's publication, between 4.6 and 7.1 billion tons of GHGs were emitted annually because of livestock production, which accounted for 15-24 percent of GHG production. CAFOs are the fastest growing form of livestock production to keep up with an ever-increasing consumer demand for animal protein, and as such, are contributing to global warming. For example, 14.8 kilograms of carbon dioxide (CO_2) are released for the production of 1 kilogram of beef, while 1.1 kilograms of CO_2 is released per kilogram of chicken produced and 3.8 kilograms of CO_2 is released per kilogram of pork produced.

To determine future GHG emissions from livestock production, Fiala models future demand for meat consumption. He finds that, by 2030, beef consumption will increase by 32 percent, chicken consumption will increase by 110 percent, and pork consumption will increase by 73 percent. This implies that, assuming CAFOs are utilized to meet these increases in demand, GHG emissions will rise as well. As Fiala states:

> The total potential greenhouse gas emissions, if all meat were produced in the same method as the US CAFO system and there was no deforestation[3], would have been 1.3 billion tonnes of CO_2 equivalent in 2000. This number increases by 17% to 1.5 in 2010, 33% to 1.7 in 2020 and 47% to 1.9 billion tonnes in 2030. In 2007, the total CO_2 output was approximately 30 billion tonnes of CO_2 equivalent. If future CO_2 production is to stay at the current amount, meat production accounts for 5.0% of total production in 2010, 5.7% in 2020, and 6.3% in 2030. (417)

To address this externality, Fiala suggests that GHG capture systems are a potential solution. Capture systems catch emissions so that they can be used for other purposes, such as for energy or electricity at the CAFO. However, these systems are very expensive. Even though they lower the energy costs to the firm, this benefit is not enough to outweigh the costs associated with implementing the capture systems. There must be a credit or subsidy of approximately \$12/tonne CO_2 for capture systems to be economically feasible. However, since the externality cost of CO_2 has been estimated to be between \$2-\$10 per ton of CO_2 emitted in economically developing countries and \$1/tonne in economically developed countries, this is not a viable solution as of now.

Fiala also proposes increasing regulation for CAFOs. Such measures include changing working conditions in CAFOs and welfare conditions for the livestock raised in CAFOs. These policies would increase the production costs of meat, making it more expensive. However, these changes would likely be unpopular, as producers will object to their increased costs (many

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[3] In tropical areas especially, space for plantations/farms/CAFOs is created by cutting down rainforests. Not only does the expansion of CAFOs increase CO_2 emissions because of the livestock, the biomass that was on the land is usually burned, liberating the carbon that had been fixed in the biomass. Furthermore, there are no longer trees or other plants on the land to fix atmospheric CO_2 for photosynthesis. For this reason, Fiala's estimations are likely low.

CAFOs are currently subsidized), and consumers will be unhappy with having to pay more for or not being able to afford meat.

EXTERNALITIES OF CAFOS: PUBLIC HEALTH

Another type of externality caused by CAFOs affects the public health of the affected area. These often arise from the pollution associated with CAFOs, but their effects are seen in a different way. For example, Sneeringer (2009) studies these externalities. She measures infant mortality caused by air pollution from increases in the number of animals in livestock operations; the data are collected and grouped based on the counties in which the operations are located. The health outcome is determined as a function of the number of animal units, a vector of observable regressors that vary by the location and time period, a constant term that absorbs unobserved characteristics of the county or state that remain constant over time, a constant term that absorbs unobserved events that affect all areas in a period, and a dummy variable that absorbs events that affect all the counties in a state. Infant mortality is used as the health outcome because if adults were used, there would be problems with previous life exposure and migration (since pregnant women and infants have low migration rates, the effect from the CAFO would be seen in the county where the exposure took place).

Her results suggest that "a 100,000 animal unit increase in a county corresponds to 123 more deaths of infants under one year per 100,000 births, and 100 more deaths of infants under twenty-eight days per 100,000 births. A doubling of production induces a 7.4% increase in infant mortality" (124). This information is then used with the EPA's value of a statistical life ($6.2 million) to calculate that the resulting externality is equal to $21.7 billion.

Another example of public health externalities caused by CAFOs involves antibiotic resistance. Centner (2003) discusses these effects. Since so many animals are kept in close proximity to each other in CAFOs, diseases and infections run rampant through these populations of animals. To keep their farm animals from being sick, workers in CAFOs often include antibiotics in the animals' feeds to keep them from getting infections. Furthermore, low doses of antibiotics can facilitate growth and weight gain in livestock. This is profitable for the firm, as larger animals with more meat are more desirable for the market. Additionally, antibiotics can improve the carcass quality of livestock. In fact, in 2003, almost 27 million pounds of antibiotics were administered to livestock in the United States. To put this in perspective, only 3 million pounds were administered to humans.

However, despite the presence of these antibiotics in the animals' feed, not all of the infection-causing bacteria are killed. They survive and continue to pass on their resistant genes to their offspring, creating bacteria that are immune to common antibiotics. Since the bacteria that infect livestock are biologically similar to those that infect humans, this practice renders the antibiotics ineffective for therapeutic use in humans. This requires that new antibiotics be developed in the laboratory, which is an expensive and time-consuming process. Centner then cites a startling statistic from the American College of Physicans-American Society of Internal Medicine: "Society expands US $30 billion per year due to the cumulative effects of antimicrobial resistance" (435).

EXTERNALITIES OF CAFOS: PROPERTY VALUES

Another external effect caused by CAFOs is their impact upon property values near where they are located. Kim, Goldsmith, and Thomas (2010) examine the property values of homes near CAFOs in rural Craven County, North Carolina, to quantify the negative consequences of being located near a CAFO. This value is then compared to the economic benefits from CAFOs—such as increased employment opportunities, more commercial activities, and increased tax revenues—to determine "[h]ow livestock producers and their constituents might strike a compromise…[using] a unique method, the ratio of economic impact to costs (EC/I), by which the benefits arising from livestock production might be directly used to compensate adversely affected homeowners" (29-30). They choose to quantify effects from CAFOs using property values because they are more easily quantified than impacts upon human health or the environment. While previous studies had found between a 4 percent to 26 percent reduction in property values because of their proximity to CAFOs, they add that no studies looked at the potential economic benefits of CAFOs to an area. Thus, they choose to calculate and then compare these statistics to determine amore efficient way of compensating those harmed by CAFOs without overpenalizing the CAFOs.

The authors then examine the property value of land parcels as a function of the value of nearby homes, the square footage of homes, its number of rooms, the number of bathrooms, the acreage of the lot, the house's age, the median income of the area, the distance to the central business district, the distance to open spaces (parks, etc.), the distance to schools, the number of hogs on a particular farm divided by the distance to the house, and a dummy variable for if the animal feeding operation (AFO) is a CAFO[4]. They then use an input-output analysis to show hog farms' impacts—direct, indirect, and induced—upon Craven County, NC. The direct effects are the private benefits to the owners of the hog farms. The indirect benefits are the benefits from the farms' purchases. The induced benefits are the spending by the farms' employees. These benefits

4 Animal feeding operations (AFOs) are livestock production areas that do not meet all the criteria to be classified as CAFOs.

are then compared to the public costs in an economic impact to cost (EC/I) ratio, which is determined for all houses affected by farms in Craven County. While most farms have an EI/C>1, showing that the economic impact from these farms is greater than the cost, CAFOs located nearest residential areas had the lowest EI/C ratios (0.38), indicating that the costs associated with these CAFOs far outweigh the benefits.

Kim, Goldsmith, and Thomas emphasize in their conclusion that policy makers need to account for both the "goods" and "bads" associated with livestock farming. Furthermore, location/proximity to residential areas needs to be taken very seriously when planning or developing CAFOs. While EI/C ratios are a cardinal ranking measure, they fail to account for social welfare. Even so, these data can be used to calculate livestock taxes to compensate those harmed by CAFOs and reduced property taxes for those whose property values fall due to their proximity to CAFOs in order to correct these externalities.

CONCLUSION: INTERNALIZING THE EXTERNALITIES

CAFOs have many effects outside of what impacts the firm itself experiences. Thus, externalities exist. Although some of these may be positive in terms of economic growth and activity in the areas where they are located, the vast majority of these externalities harms the outside parties through environmental degradation, damage to public health, and lowered property values.

Theoretically, these consequences can be corrected by internalizing the externality. That is, by assuring that the CAFOs are fully paying for their actions. However, in practice, this is easier said than done. As described by Chakravorty et al. (2007): "One way to mitigate the environmental impact would be to adopt tax and subsidy policies that shift agroindustrial production…While market mechanisms or the "polluter pays" principle are appropriate from a theoretical point of view, the task of regulation is complex, and the political will to do so is inadequate" (334). Regulation to correct for negative externalities would cause CAFOs to become more expensive, and these increased costs would be passed on to consumers in the form of more expensive products produced from CAFOs, such as meat. Though such policies would be economically feasible and could be Pareto improvements, it is not politically feasible to make such changes. Fiala (2008) touches on this point as well, suggesting that increasing regulation on CAFOs will increase costs, which will cause production to decrease, which will cause prices to rise which will cause the equilibrium amount of meat/CAFO products produced to decrease:

> A difficulty with this solution is that it is politically challenging from both producers and consumers. Producers may oppose it as it will decrease profits. Far from being highly regulated, meat production in the US and many other countries is subsidized. Consumers may object because of lower access to meat. In addition, educating consumers is not likely to have a great impact as most consumers are already aware of conditions but are not willing to demand change. (418)

Other types of regulations to correct these externalities have been proposed as well. For example, one possibility is to limit the amount of manure that can be spread on land in order to decrease the amount of water contamination. However, this policy has been found to actually *increase* nitrogen pollution. Since the policy limits the amount of manure that can be applied to land, more land is being used (Kaplan et al. 2004). Thus, such policies are ineffective.

Another way to regulate CAFOs is to allow them to develop their own unique alternative performance standards (APS). Pease and Bosch (2004) examine APS policies and determine that allowing certain CAFOs to develop their own APS strategies to keep their emissions in compliance can be more successful than by the EPA simply imposing mandates. However, they also emphasize the difficulties in carrying out these plans and monitoring them to assure that they are as effective as they are supposed to be. Furthermore, there are legal issues within the

Clean Water Act that may make policies such as these prohibited, and allowing CAFOs to decide upon their own emissions controls may be publicly unpopular when CAFOs are seen as the source of the problem in the public's eye.

CAFOs are the source of numerous externalities that affect many people. The harm that they cause will be difficult to quantify and correct given current environmental, economic, societal, and political conditions. Though there are potential solutions or mechanisms that could be used to correct these externalities, problems with implementation are likely to arise.

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