

BA Business and Management

Economics of sustainability: BMSP6007

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Assessment 1: 2500 word essay

‘Regarding chlorofluorocarbon-related market failure’

Executive summary

This essay was written on the topic of the market failure and negative externalities of production as a result of chlorofluorocarbons (CFCs). A market failure is described by AP Microeconomics (n.d. a) as an inefficient allocation of goods or services due to marginal benefit to consumers not being equal to the marginal cost of production. A negative externality of production is a spillover effect on third parties as a result of production of goods or services.

CFCs were developed in the 1930s and became highly used for their nonreactive nature being conducive to various industrial applications. They have since been proven to disrupt stratospheric ozone levels in large amounts and cause drastic disruptions in ozone levels during Antarctic spring-time. This has a severe impact on human health, with increased exposure to harmful UV-B rays contributing to a variety of ailments.

Government intervention was the solution used for this problem, with the 1985 Vienna Convention for the Protection of the Ozone Layer and the later, more effective, 1987 Montreal Protocol both being enacted by the United Nations. The Montreal Protocol laid the plans for

a stepwise phasing out of ozone-depleting substances such as CFCs and is widely known as the only UN agreement to be universally ratified; the Protocol was shown to be a success as ozone levels were saved by up to 5% in the southern hemisphere alone by 2001, just over a decade after the agreement.

The theoretical market-based approaches taxation and tradable permits were examined as potential alternatives to government intervention. Examination of these approaches led to the conclusion that, despite their usefulness in many cases of market failure, this situation was simply too dire to be left in the hands of the market for longer.

In conclusion, the great success of the Montreal Protocol is a testament to the usefulness of government intervention in the case of market failure, but it is not to say that it is the best approach for every case. Under less alarming circumstances, a market-based approach would likely have similar levels of success.

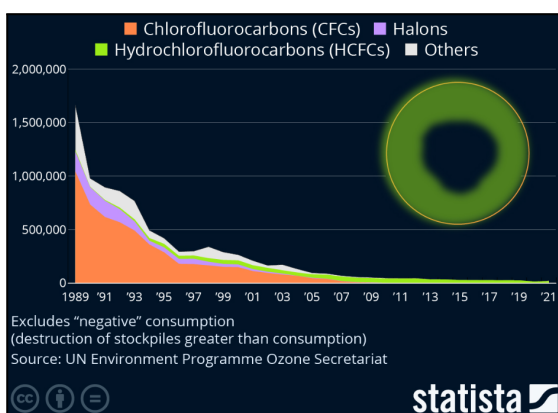
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Introduction to essay and key terms

This essay has been written on the topic of the market failure and negative externalities of production regarding chlorofluorocarbons — referred to as CFCs — using both applied economic theory and real accounts of the actions that came of the issue.

The graph below (Buchholz, 2023) shows a global response to the CFC crisis; consumption of CFCs halved from its 1989 peak in four years and, by 2007, had largely been eliminated. This is a near-total elimination in just under twenty years, showing that remarkable feats of change are indeed possible with a coordinated, committed response; this essay will cover how this elimination of CFCs came to be.



It is first important to ensure understanding of the terms 'externality' and 'market failure', which are

heavily reliant on the illustration of economic consequences.

Externalities

AP Microeconomics (n.d. a) sets the scene for externalities by using the idea of market failure, described as an allocation of goods or services which is allocatively inefficient; in other words, it does not reach the point at which marginal benefit to consumers equals marginal cost of production.

Marginal cost or benefit denotes the change in total cost or benefit when the quantity of a good produced is increased by one unit; in a free market, the demand curve is equal to the marginal private benefit and marginal social benefit curves, so $D=MPB=MSB$.

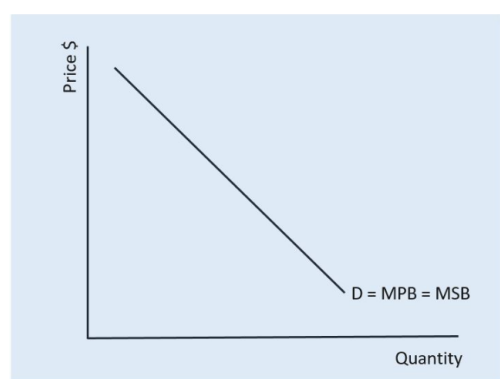


Figure 1: The demand curve = MPB = MSB

The demand curve (AP Microeconomics, n.d.)

Mentioned above, marginal benefit is the additional utility gained from consumption of a unit of a good or service, as well as the maximum amount that someone is willing to pay for one more unit. Marginal *social* benefit denotes the benefit to society from the consumption of an additional unit.

The law of diminishing marginal utility states that, as consumption increases, the marginal utility derived from a unit will decrease; the downward-sloping demand curve is based on this notion of diminishing marginal benefit.

The spillover on third parties from production or consumption of these goods is labelled an externality. This is explained by AP Microeconomics as being an external cost or benefit which may go unconsidered by consumers or producers when consuming or producing a good or service, illustrated in the image below.

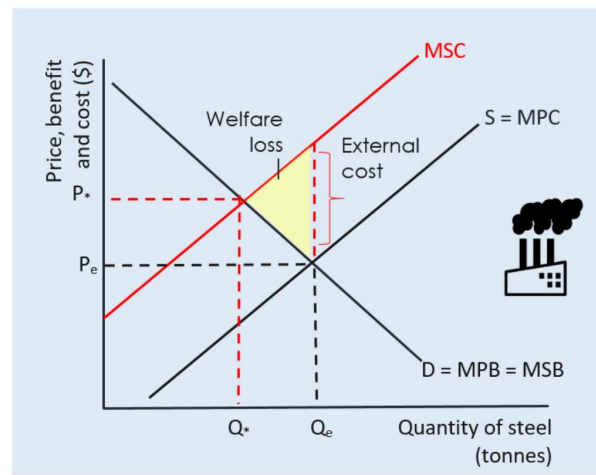
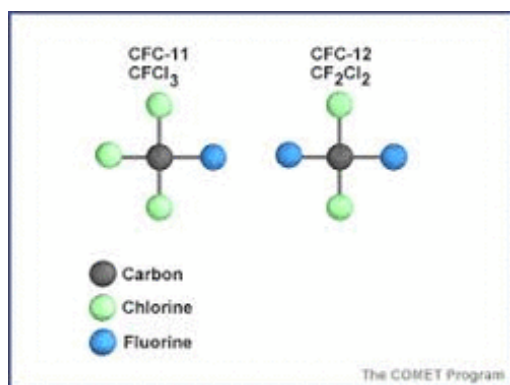


Figure 5: Negative externalities of steel production: $MSC > MPC$

Chlorofluorocarbons: nature and history

This section aims to conduct a brief review of the history of chlorofluorocarbons.

Plummer and Busenberg (2000) detail that the compound is a synthetic alkane, invented in the 1930s as an alternative to ammonia and sulphur dioxide for refrigeration. CFC-12 began production in 1931 and CFC-11 began in 1936. These compounds are nonflammable, nonexplosive, noncorrosive and low-toxicity, making them very conducive to applications in industry and as refrigerants. The compounds are primarily used as coolants, blowing agents and aerosol propellants. It is estimated that CFCs in propellants were released within 6 months of sale on average, within less than a year for blowing agents and within 1-10 years for refrigeration and air conditioning. Estimates for the atmospheric lifetimes of CFCs are 45 years for CFC-11, 87 years for CFC-12, and 100 years for CFC-113. Production and atmospheric release of CFCs rose very quickly through the 1970s and 1980s, becoming a prime contributor to stratospheric ozone depletion.



CFC-11 and CFC-12. (NESTA, n.d.)

Although this will be covered in greater detail in the following section, the primary issue brought about by use of CFCs is the depletion of stratospheric ozone. Rowland's (1989) hypothesis that CFCs destroy the ozone layer was validated upon the revelation in 1985 that ozone levels drastically decreased during Antarctic

spring-time. Being commercially useful for their lack of reactivity, CFCs survive unchanged in most applications and are often let into the atmosphere after. In addition, the Earth's natural 'sinks' — photodissociation, rainout, and oxidation — are not effective in removing CFCs from the atmosphere. A return to 1960s levels of stratospheric chlorine — one indicator of the effects of CFCs — may require several hundred years, thus serving as a lasting reminder of humanity's ability to alter nature on a global scale. Ramanathan (1975) mentioned that CFCs possess strong infrared bands, which absorb surface radiation and emit it at atmospheric temperature, thereby contributing to the greenhouse effect.

An article by Newman *et al.* (2009) summarised a series of studies as bearing the indication that the majority of the ozone layer would have been destroyed by 2065 with continued CFC usage. Thankfully, research into this topic culminated in a timely scientific assessment of ozone depletion by the WMO, providing the consensus that CFCs and halons pose a serious threat to the ozone layer. This led to the Montreal Protocol agreement being negotiated in 1987.

Concluding this section, a stark contrast between outlooks on the CFC industry has been depicted; the vast promise across many applications initially offered to its inventors, compared with the reality of their environmental impact as understood in modern times. When production of CFC-12 and CFC-11 began in the 1930s, (Plummer & Busenberg, 2000) the promising outlook of the industry was shown to them. Further in time, the latter outlook of the industry is shown, as it has since been revealed that CFCs are destroying the ozone layer (Rowland, 1989) and accelerating the greenhouse effect (Ramanathan, 1975). Now that the negative effects of these compounds have been explained, the failure of the market to self-regulate and prevent this environmental disaster will be covered in the next section.

CFC market failure

Market failure was briefly described in the introduction as the allocation of goods or services being allocatively inefficient (AP Microeconomics, n.d. a). This often means failure to achieve correct outcomes for individuals and society due to a misallocation (AP Microeconomics, n.d. b). In this case, the market failure at hand is a negative externality of production.

The topic of market failure was discussed by Ledyard (1989), being said to involve a fundamental theorem of welfare economics:

“(1) if there are enough markets, (2) if all consumers and producers behave competitively, and (3) if an equilibrium exists, then the allocation of resources in that equilibrium will be Pareto-optimal. ... Market failure is said to occur when the conclusion of this theorem is false”

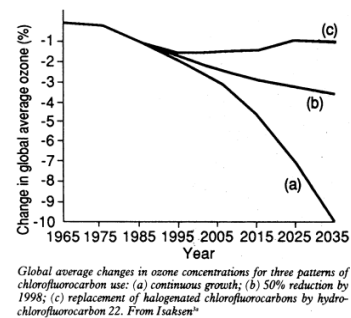
The standard argument for correcting market failure, mentioned by Ledyard, is that, if everyone can be made better off by correcting said inefficiency, they should be made such.

Datta-Chaudhuri (1990) provided a brief history of market failure; he attributed the genesis of the idea to the development economics of the 1940s, alongside the success of Keynesian economics in combating the Great Depression and the successful reconstructive efforts of the post-WW2 Marshall Plan. These combined events helped create an intellectual consensus on the power of the ‘visible hand’, as opposed to the invisible.

CFCs can be related to market failure due to the potential impact of a destroyed ozone layer on human health. Jankowski and Cader (1997) summarised the destruction of the ozone layer as causing an increase in environmental ultraviolet (UV) levels; this has the potential to increase skin cancer rates, contribute to the development of cataracts and reduce immunological strength.

Anwar *et al.* (2016) expand on this by mentioning that stratospheric ozone disturbances and global warming cause the penetration of the troposphere by a greater amount of UV rays. In addition, hydrogen peroxide — a toxicant which renders water unfit for drinking — is created in greater amounts due to UV penetration; this same penetration also disturbs processes critical for the productivity of crop harvests, which has the potential to cause food shortages.

The issue of UV exposure was explained by Godlee (1991) to be a result of UV-B, which falls within the photoabsorption spectrum and has the potential to cause damage to DNA. Furthermore, documentation exists of UV-B causing an immunosuppressant effect, thereby potentially contributing to one’s risk of skin cancer and other diseases. The following chart plots the projected change in ozone concentration as of 1991 based on three trajectories: the industry continues growing, it is curtailed by 50% in 1998 and it is fully supplanted by hydrochlorofluorocarbons.



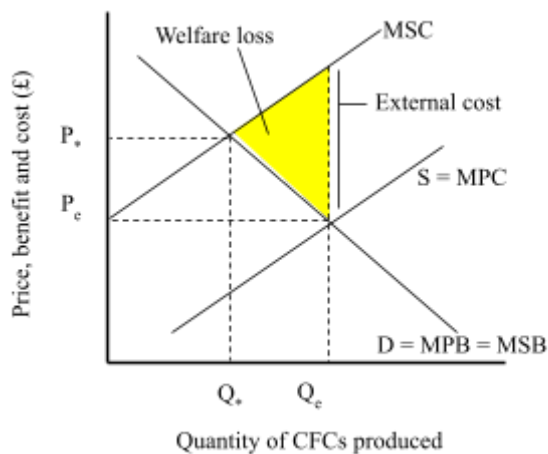
(Godlee, 1991)

The aforementioned findings clearly show that continued usage of CFC represents a detriment to human health via the disturbance of the stratospheric ozone layer.

Represented on the graph below, these effects constitute a negative externality of production. In theoretical terms, It is assumed in the chart that there are only external costs associated with the production of CFCs and no external benefits. Because social costs are the total of private and external costs, and each unit of CFC produced

contributes to the breakdown of stratospheric ozone, marginal social benefit (MSB) is therefore equal to marginal private benefit (MPB). The free market price of CFC is too low, at P_e instead of P_* , and the output of CFC is too high, at Q_e instead of Q_* .

Profit maximising firms set their quantity of production at Q_e , where the MSC curve intersects with the MPC curve, despite this level of output not being socially optimal.



Negative externality of production chart adapted from AP Microeconomics (n.d.)

This section of the essay has pointed out the market failure of continued, unimpeded usage of CFCs. Not only do they cause greater exposure to harmful UV-B rays but they are also contributors to the greenhouse effect, which still affects the planet today. The standard argument for intervention in the case of market failure — highlighted by Ledyard (1989) — is that, if anyone can be made better off by correcting an allocative inefficiency, they should be made better off.

Solution to market failure

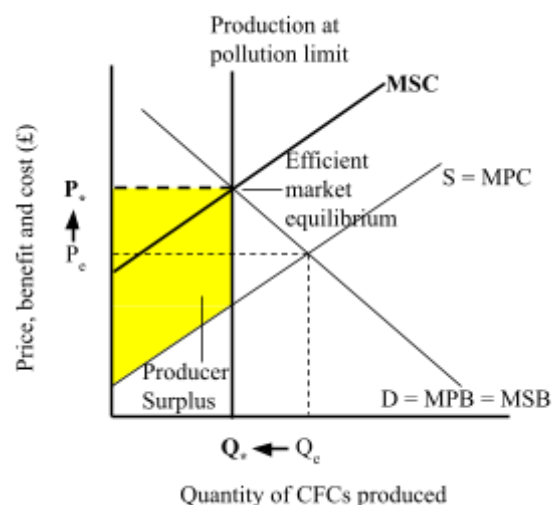
The United Nations Environment Program (UNEP, n.d. a) site indicates that the primary government response to the crisis was to devise the Vienna Convention for the Protection of the Ozone Layer and the Montreal Protocol.

Morrisette's (1989) review of policy responses to stratospheric ozone depletion underscored the 1987 Montreal Protocol as a landmark agreement, given that it was the first international treaty for ameliorating a global atmospheric problem before conclusive detection of serious environmental impacts. The 1985 Vienna Convention, though with less striking results, played an important role in legitimising stratospheric ozone depletion as an international issue and laying the groundwork for the former.

A UNEP webpage (n.d. b) detailed that the Montreal Protocol was designed to phase down the production of ozone-depleting substances (ODS), such as CFCs, in a stepwise manner. Different timetables were permitted for developing and developed nations, and subsequent amendments were ratified for the purpose of phasing out additional ODS; a notable example of this was HFCs, which were used as alternatives to CFCs but also contributed to the greenhouse effect.

A study by Egorova *et al.* (2001) assessed the impact of the Montreal Protocol on atmospheric ozone, coming to the conclusion that it began to have an impact on the ozone layer by 1996-1997 — roughly a decade after the agreement — saving up to 2% of the total ozone in the northern hemisphere and up to 5% in the southern hemisphere at the time of writing.

Returning to theoretical economics, the stepwise manner of reduction used in the Montreal Protocol could be shown on a chart by adding a pollution limit to the negative externality chart. This limit would be reduced over time for the stepwise phasing out of CFCs.



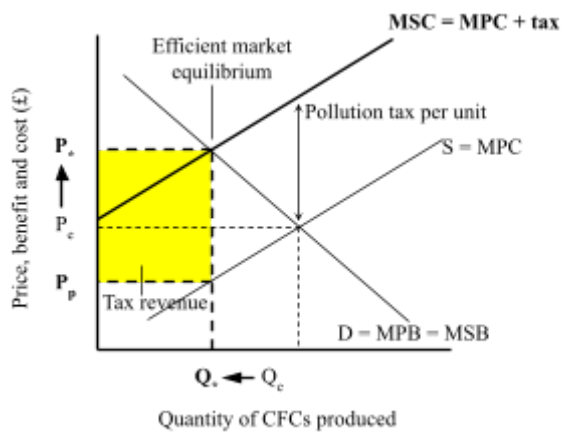
Pollution limit chart adapted from AP Microeconomics (n.d. a)

In this chart, a pollution limit is imposed, restricting production to achieve an efficient market equilibrium; the new market price is equal to MPB and MSC.

Suitability of market-based policies

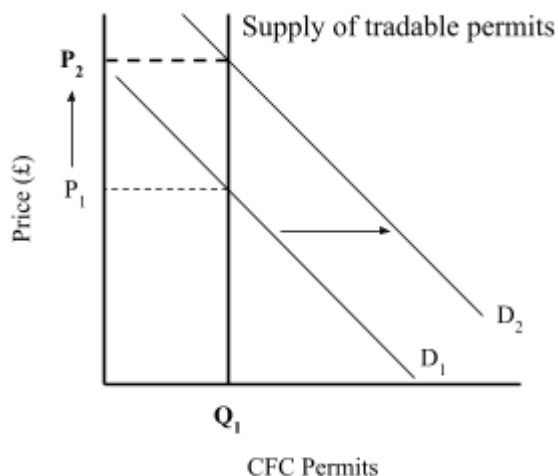
This subsection will evaluate whether market-based policies could have been used to stir the invisible hand of the market instead of relying on government intervention.

Two applicable market-based models for reducing pollution are taxes and tradable permits. The first, taxes, charge producers at a rate equal to the marginal external cost; in this way, the marginal social cost curve becomes the supply curve, the government collects tax revenues equal to the amount shown by the rectangle and supply decreases from $S = MPC$ to $MSC = MPC + \text{tax}$.



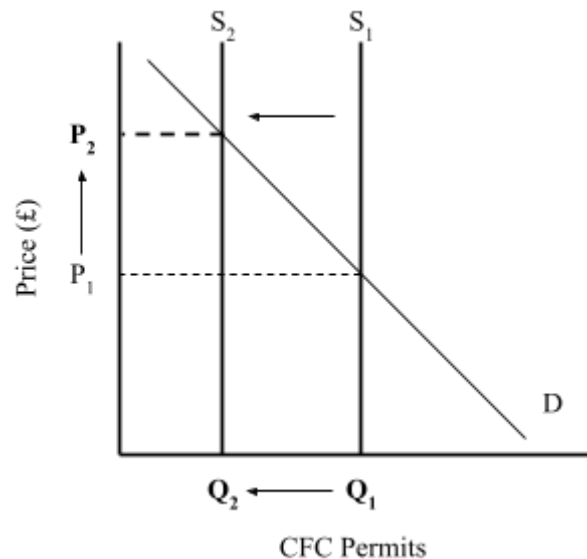
Indirect taxation chart adapted from AP Microeconomics (n.d. a)

The second market-based policy is tradable permits, which involve selling pollution rights to producers who can then trade these among themselves.



Tradable permits chart adapted from AP Microeconomics (n.d. a)

The above portrayal of the market for tradable permits shows a limit on the amount of CFCs used in production. As the economy grows, both the demand for and, in turn, the price of the permits will increase. The chart below shows that, as the government reduces the supply of permits over time, the demand for them will decrease as their price increases, reducing CFC usage overall.



Permit change chart adapted from AP Microeconomics (n.d.)

While — in theory — market-based policies could stand to provide a simple way of curbing CFC usage, the situation was in reality too dire for experimenting with taxation and permits. A swift and unified response was necessary for curtailing the negative production externality of CFCs within an acceptable time frame; setting up permits would involve many measurements of economic impact to gauge the appropriate price of a permit, which would undoubtedly cause controversy among disagreeing parties. The end result of an attempt at implementation of a permit, in this case, would likely be much arguing and little progress at a time when progress was sorely needed. Taxation fares little better in this regard: the level of tax would need to be carefully considered as too high a level would cause severe economic damage while too low a level would not disincentivise the usage of CFCs as intended.

Overall, the Montreal Protocol proved to be an effective form of government intervention through its decisive phasing out of CFCs and inclusion of a separate timescale for developing economies. Its success is proven by the fact that it is the only UN environmental agreement to be universally ratified, showing a global unity on this issue. (UNEP, n.d. a)

Conclusion

Concluding this essay, CFCs used in the production of aerosols and refrigerants — among other applications — were shown to contribute to the greenhouse effect and to be detrimental to stratospheric ozone; over time, a depletion in this ozone was exposing people to greater amounts of harmful UV-B rays, which represented a negative externality of production. The solutions which were implemented by governments included the Vienna Convention, regarded as a precursor, and the Montreal Protocol. Additionally, theoretical market-based approaches were examined, although the Montreal Protocol was theorised to have been likely to outperform any market-based solutions.

The great success of the government-led Montreal Protocol in curbing the usage of CFCs is a

testament to the fact that government intervention can provide swift correction to market failure in times of crisis. This is not, however, to say that government intervention is always the approach of choice for dealing with market failure; under less alarming circumstances, a well-planned, market-based approach such as taxation or permits would just as successfully be able to curb the usage of pollutants resulting from production.

Word count: 2491

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