Carbon Pricing in Canada:
A Performance Review

by

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Abstract

The purpose of this major research paper is to examine the effectiveness of carbon pricing systems, in terms of their political longevity and their environmental robustness. It aims at comparing carbon taxes with cap-and-trade regimes in the Canadian context, to investigate which one of these two approaches can withstand electoral political change, and to assess whether such systems can result in GHG emission reductions. The research also examines the possibility of the simultaneous implementation of carbon taxes and cap-and-trade mechanisms. Furthermore, it explores whether carbon pricing systems could be implemented with other climate change mitigation policies. In addition, it identifies limitations and trade-offs that the implementation of carbon pricing faces. Finally, it provides policy recommendations for advancing such systems in Canada in particular. The paper contributes, as well, to the understanding of whether carbon taxes really make sense by highlighting the economics of emissions reduction and turning the spotlight on the welfare analysis of negative externalities.

Foreword

Although this major paper focuses on the performance of carbon pricing systems in Canada, it is based on a broader intellectual context and components that have guided my research within the MES program. Prior to my MES studies, I had completed a graduate program in Disaster and Emergency Management. In that program I became familiar with the provocative ideas of “managing without growth” and “re-imagining capitalism”. Starting the MES program, initially I wanted to investigate what vulnerability means from the perspective of ecological economics, and especially had ambition to explore whether re-imagining capitalism puts our planet on the right track towards Sustainable Development (SD). In my plan of study, therefore, I chose the following area of concentration: Towards Sustainable Development or Corporate Bad Ethics? This area of interest was followed through three interlinked components: Business Ethics and Economics; Sustainable Development; and Political Economy.

In the MES program, particularly, I obtained general knowledge about business strategies for sustainability as well as the main challenges businesses are facing today and probably in the future within the global context. Also, I consolidated my understanding and grasp of the social and environmental aspects of sustainability and became interested in renewable energies and carbon pricing – as reasonable pathways and solutions to climate change. The structural problems that carbon pricing systems suffer from as well as the widespread lack of understanding that carbon taxes really make sense were eye-catching.

On the verge of the climate tipping point, humans have no choice but to organize their economic activity more thoughtfully so that economic development and conservation of the natural world can go together. Meanwhile, economists have raised hopes that the power of capitalism and economic tools such as carbon pricing systems can help humans protect the environment. Despite their theoretical foundations in economics, nonetheless, these systems seem to suffer from pitfalls that undermine their effectiveness. The literature does not contain many studies focused on these structural shortcomings, however. This is exactly what makes this study relevant and potentially influential.

In memory of my mother whose words molded my past, drive my present, and shape my future ambitions: “Stand for the right and pay the price for it. No cost is too great son, to do the right thing.” Her voice still reverberates in my heart.

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Introduction

The scientific community, as summarized by the IPCC's definitive reports, and as stated by Heal (2017), has reached a consensus that, due to the human emissions of greenhouse gases (GHGs), the Earth is warming and the consequences of continued warming are expected to be severe. For a few decades, efforts to find solutions to climate change have been focused on curbing GHG emissions, particularly carbon dioxide. Nonetheless, given the fact that the benefits of addressing the growth of GHG emissions almost certainly outweigh the costs – and that the effects of increased emissions remain in the atmosphere for so long and affect the welfare of future generations – concerted global action to solve the problem is not easily achievable. Who should pay for responses to climate change, and how much should be spent on it, are matters of ongoing debate due to factors like free riding and global geopolitics.

Despite the ongoing debate on such matters, the international community has agreed, so far, that shaping behavior through market mechanisms such as carbon taxes or cap-and-trade regimes are the most effective ways to reduce GHG emissions. The Kyoto Protocol, adopted in 1997 and taking effect in 2005, was in fact the first attempt to implement a global cap-and-trade system (Henderson et al., 2018). Today, the idea of providing incentives to reduce GHG emissions and making polluters pay seems to be reasonable and, at least from the standpoint of the theory of economics, doable. Economists are especially fond of carbon taxes and cap-and-trade systems, as the most acceptable carbon pricing tools to combat global warming to date.

These market-based approaches are not new. Since the early 1990s countries and regions such as Finland, Sweden, Great Britain, Australia, and the provinces of Quebec and British Columbia in Canada have adopted carbon taxes. Cap-and-trade systems have been explored as well by many jurisdictions. The European Union emissions trading system (EU ETS) is a prominent international example. China has cap-and-trade systems in operation both at the provincial and city scales. Another example is the joint cap-and-trade market originally established by Quebec, Ontario and California. Today more national and subnational jurisdictions as well as private sector entities are adopting carbon pricing. According to a recent World Bank's (2018) report, to date 51 carbon pricing initiatives worldwide have been implemented or are scheduled for implementation; this consists of 25 emissions trading systems (ETSs), mostly located in subnational jurisdictions, and 26 carbon taxing initiatives primarily implemented on a national level. The report asserts that carbon pricing can serve multiple environmental and social objectives. Nonetheless, there is still a long way to go to reach the reality of a sustainable development path. Ahonen et al. (2017) provide details about current developments in carbon emissions and climate law.

While carbon pricing is becoming a global trend, there is limited agreement on the preferability of either of these two systems over the other. Theoretically, carbon taxes and cap-and-trade can perform roughly the same; that is, they are different means to the same end: generating revenue for governments to put to good use (Aldy, 2017). However, their implementation nuances bring different challenges depending on the local capacity and infrastructure levels of each region. Each jurisdiction, therefore, must decide on its own approach to pricing carbon. There is no one size or type that fits all.

The implementation of EU ETS has not been proved yet as a successful case of a cap-and-trade regime. Ontario's defunct cap-and-trade regime is another example that illustrates the political challenges that can be faced by such systems. On the other side of the coin are the carbon tax systems of Sweden and the province of British Columbia in Canada, which represent politically robust examples of successful carbon pricing. Such evidence brings to the forefront this conjecture: Are carbon taxes indeed superior to cap-and-trade systems? Can carbon taxes and cap-and-trade systems be combined with each other and other complimentary policies? More specifically, this research analyses the two market approaches to carbon pricing currently in use here in Canada to explore those questions.

This paper seeks to answer the following questions: Are carbon taxes more effective - i.e. politically withstanding and environmentally robust - than their counterparts, cap-and-trade systems? Can carbon taxes and cap-and-trade systems be implemented simultaneously? Can carbon pricing be implemented with other climate change mitigation policies?

Ethical Foundations: The Tragedy of The Commons

This paper is not intended to be a rudimentary analysis of climate change which has become a buzzword in the mainstream socio-economic space. Instead, maintaining the fact that the observations and predictions made by scientists (as summarized at the most recent IPCC's reports) have left no doubt about the consequences of doing business as usual for the planet Earth and its inhabitants, the paper focuses solely on climate change solutions. To provide context, this section of the paper focuses on the tragedy of the commons which – as the underlying cause of global warming – has brought humans in the modern era nothing but misery.

If economics is about the actions of optimizing economic units (e.g., individuals, firms, and governments) as well as the interactions between them, maintaining that such economic units are rational decision makers who decide based on self-interest, the aggregation of their behavior cannot always serve the common good – despite the optimism of Adam Smith's "Invisible Hand". That is because the world is not full of angels. In other words, there are cases of market failure (for instance, negative externalities) in which the aggregation of the actions of optimizing economic units results in a bad outcome for all; this is, in essence, the tragedy of the commons.

The tragedy of the commons, in the language of economics, is in fact a generalized prisoners' dilemma; a simultaneous-move game in which each individual player (as a separate economic unit) follows its own dominant strategy disregarding the decisions of other stakeholders. While cases of prisoners' dilemma typically lead to an outcome which is pareto inefficient (i.e., there is another outcome that makes at least one economic unit better off and nobody worse off), even pareto efficiency (as defined in conventional economics) is not always fair. Moreover, even trade that might alleviate market inefficiency in certain situations, does not always work well. Sometimes only are just-in-time negotiations and collective actions that could help solve the tragedy of the commons. From this perspective, worldwide carbon pricing would probably be the most appropriate global response to the tragedy of climate change.

These foundational subjects will be complemented later in the paper by a brief discussion of prisoners' dilemma, simultaneous-move games, and negotiation. Moreover, for interested readers a concise timeline of climate change is provided in Appendix A.

The tragedy of the commons is the root cause of dirty kitchens in college dorms, environmental problems like littering, traffic congestion, overfishing, air pollution, and climate change. All are the same. Only the context and scale are different. The problem is that humans are smart, usually driven by self-interest and not-in-my-backyard (NIMBY) philosophy in making decisions. This is, in fact, the logic behind the idea of the economists who hope making fossil fuels more expensive would solve the complex problem of global warming and its dire consequences. The tragedy of the commons is an ethical issue which could hopefully be managed by economic tools and the power of capitalism.

In the context of climate change and carbon pricing, the common-pool resource is the shared atmosphere. In that regard the tragedy of the commons – the topic of this chapter – can be discussed from two perspectives: ethics and common sense, and the theory of economics.

In his seminal paper, Hardin (1968) quotes – as follows – the conclusion of Wisner and York (1964) in an article on the future of nuclear war:

> "Both sides in the arms race … confronted by the dilemma of steadily decreasing military power and steadily increasing national security. *It is our considered professional judgment that this dilemma has no technical solution.* If the great powers continue to look for solutions in the area of science and technology only, the result will be to worsen the situation."

By quoting Wisner and York, Hardin wants to refer to a category of problems that have no technical solutions. Population growth, as he highlights, is an example of such problems. According to him, no-technical-solution problems might demand changes beyond the techniques of natural sciences; i.e., requiring changes in human values and ideas of morality. Particularly, he refers as well to the Tragedy of Freedom in a Commons as the rebuttal to Adam Smith's "Invisible Hand", and relates the pollution of water and air, as another no-technical-solution problem, to the growth of population. "Freedom in a Commons brings ruin to all", he says.

Hardin (1968) also believes that the laws of society might follow the pattern of ancient ethics; meaning that an act may be quite acceptable if being judged by ancient laws, but seen as immoral at the present time due to evolution in society. Hardin asserts that problems such as pollution, which demand changes beyond natural sciences' techniques, need to legislate temperance as well. Also, in response to how to do so, he emphasizes that prohibition might be easy to legislate, though not necessarily to enforce. Hardin (1968) particularly does not believe in conscience to control the behavior of individuals. An appeal to conscience, as he says, has both short- and long-term disadvantages. According to Hardin:

> "Conscience is self-eliminating" with pathogenic effects and "responsibility is a verbal counterfeit for a substantial quid pro quo. It is an attempt to get something for nothing." (Hardin, 1968; page 1247)

In Hardin's point of view, temperance can be created particularly by coercion, and taxing is a good coercive device. To clarify this, he provides the example of a citizen who is offered carefully biased options instead of being prohibited to park as long as he/she wants to; in other words, to forbid him/her to park for so long it is enough (and of course more effective than prohibition) to make parking increasingly more expensive. To create temperance, Hardin especially recommends mutually agreed upon coercion measures; supported by the majority of people affected. In his point of view, when the lion's share of people living in a given society realize the threat to the commons, they recognize the necessity of taxes and other coercive devices to escape the horror of that threat. Quoting Hegel, Hardin (1968) particularly refers to the "recognition of necessity as freedom". He highlights as well that the current legal system of the society might be destructive, and those who might be bothered by any change – and probably call it unjust – should accept the reality that injustice (even if it would be the case, as they want to name it) is preferable to total ruin.

Hardin's (1968) "The Tragedy of the Commons" is an insightful article. Nonetheless, it is criticized by Ostrom (2008) for confusing open-access commons with commons that are the joint property of a community. Ostrom differentiates between the two types of the commons as follows:

> "Commons refer to systems, such as knowledge and the digital world, in which it is difficult to limit access, but one person's use does not subtract a finite quantity from another's use. In contrast, common-pool resources are sufficiently large that it is difficult, but not impossible, to define recognized users and exclude other users altogether. Further, each person's use of such resources subtracts benefits that others might enjoy. Fisheries and forests are two common-pool resources that are of great concern in this era of major ecological challenges. Others include irrigation systems, groundwater basins, pastures and grazing systems, lakes, oceans, and the Earth's atmosphere." (Ostrom, 2008; page 11)

She also asserts that Hardin correctly points out that valuable open-access common-pool resources would be overharvested; however, his conclusion of an inevitable tragedy has been too sweeping. Later in 2012, she clarifies the problem further:

> "The classic solution to 'the tragedy of commons' problem, provided by Hardin (1968), has been to transform the resource into a private good (either by privatising it or by turning it into government property with proper monitoring.)" (Ostrom, 2012; page 58)

Unlike Hardin, who believes in a cure-all solution or a panacea to prevent the tragedy of the commons (for example by relinquishing the freedom to breed to prevent overpopulation), Ostrom emphasizes an on-going improvement by using the powers of self-governance and adaptive governance approaches. According to her, to solve problems related to the commons, it is crucial to understand that simple panaceas may work in some settings but fail in others.

Ostrom (2008) underlines the importance and effectiveness of quotas determined based on active dialogue between local users of a commons, like fisheries, in partnership with officials. She strongly believes in the role of adaptability in making communities, resources, and systems resilient and sustainable. In her article, Ostrom especially refers to some large-scale resources having been protected successfully through appropriate international governance regimes; e.g., the Montreal Protocol on stratospheric ozone, which was signed in 1987 — the same year the Brundtland report was released. She emphasizes, as well, the need to significantly reduce GHG emissions as the most pressing commons problem at a global level, and refers particularly to the European Union Emission Trading Scheme (EU ETS) — as one of the largest regimes in geographic scope aimed at curbing the emissions level.

I have found the arguments of both Hardin and Ostrom in line with the hope of economists to solve the wicked problem of climate change using economic tools (carbon pricing approaches) and the power of capitalism. Ostrom's idea of using quotas in managing the harvest of common-pool resources seems to me kind of a mutually agreed upon coercion device suggested by Hardin. While the Earth's atmosphere is a common-pool resource, cap-and-trade regimes (such as the EU ETS) are based on a quota initiative. From the viewpoint of economics, as well, such systems perform roughly the same as carbon taxes. They are different means to the same end: they make polluting increasingly more expensive, thereby curbing carbon emissions and generating revenue for governments to put to good use. It is not surprising, therefore, that these market mechanisms have been accepted internationally as the most effective ways to reduce GHG emissions. Carbon taxes and cap-and-trade regimes could be used to shape the behavior of polluters. This is a response, in the context of global warming, to the general question of Hardin concerning the unavoidable tragedy of the commons: “How to legislate temperance?” Policy makers, in fact, can use carbon pricing approaches to legislate temperance and shape the behavior of economic units.

Human Responses to Enhanced GHGs

The Nature and Extent of Climate Change

Since the Industrial Revolution, a significant amount of GHGs has been added into the atmosphere, largely by burning fossil fuels to generate electricity, heat and cool buildings, and power vehicles — as well as by clearing forests. The lion's share of enhanced GHGs being added to the atmosphere are carbon dioxide, methane, nitrous oxide, and fluorinated gases. When these gases are emitted into the atmosphere, many remain there for long time periods, ranging from a decade to thousands of years. While past emissions affect our atmosphere in the present day, current and future emissions will continue to increase the levels of these gases in the atmosphere for the foreseeable future. (U.S. Environmental Protection Agency [EPA], 2016)

Common and Stagl (2005) emphasize that what is changing the climate is the enhanced greenhouse effect. GHGs, they explain, trap heat (the energy of the sun) like a greenhouse in the lower part of the atmosphere. As more of these gases are added to the atmosphere, more heat is trapped. This extra heat leads to higher air temperatures near the Earth's surface, changes weather patterns, and raises the temperature of the oceans. The estimation of all aspects of climate change is a complex and daunting task. One reason behind such complexity, as clarified by Henderson et al. (2018), is the presence of positive feedback loops. For instance, global warming reduces the amount of snow and ice on the Earth's surface. Since snow and ice reflect more sunlight back into space, compared to exposed land, this reduction further accelerates the rate of global warming.

The Impacts of Climate Change

People and the environment are tremendously affected by the changes in weather patterns and global warming. Sea levels are rising, glaciers are melting, and plant and animal life cycles are changing. These types of changes can cause fundamental disruptions in ecosystems; thereby affecting plant and animal populations, communities, and biodiversity. Such changes can also affect people's health and quality of life, including where they can live, what kinds of crops are most viable, what kinds of businesses can thrive in certain areas, and the condition of buildings and infrastructure. Some of these changes may be beneficial to the people of certain regions. Over time, however, many more of these changes have negative consequences for people and society. (EPA, 2016)

Climate change can directly impact human health and well-being; e.g., due to heat stress, increased floods and storms. Its indirect effects can also be transmitted via impacting other plants and animals; resulting in agricultural productivity reduction or biodiversity loss, as examples.

The threat of climate change is one of the biggest issues facing the world. According to Heal (2017), the scientific community has reached a consensus on that, due to the human emissions of greenhouse gases, the Earth is warming and the consequences of continued warming are expected to be severe. Outside academia, nonetheless, there is widespread disagreement; not only on the issue, but also on how to respond to it. Some people and politicians, known as climate deniers, totally reject the role of humans in global warming. Those who accept it, look at the issue from different perspectives. Some business leaders, for example, see the viability of their firms in jeopardy as a direct consequence of climate change. Others, in contrast, consider it as an opportunity to run their lucrative businesses by promoting technologies that help communities mitigate the risks of climate change and adapt to its effects. (Henderson et al., 2018)

Responding to the Climate Problem

Three types of human responses to the enhanced GHGs are distinguishable: adaptation, offsetting, and mitigation. Adaptation simply means adjusting climate change; as examples, by building defensive walls against floods, limiting construction in flood-plain areas, or using new strains of crops to cope with higher temperatures (Common and Stagl, 2005). Offsetting is the intentional interfering of humans in the climate system; for instance, by injecting sulfates into the atmosphere to use their high reflectivity to stop part of the sun's radiation from reaching the Earth's surface (Henderson et al., 2018). Mitigation involves either reducing the amount of GHGs released into the atmosphere, or enhancing the operation of the natural sinks for the gases (Common and Stagl, 2005).

Reduction of GHGs, in its turn, includes one of the three following actions (Henderson et al., 2018):

- moving away from fossil fuels,
- improvement in energy efficiency, and

- changes in land use (e.g., agricultural, and forestry).

World Economic Forum's (2018) "The Global Risks Report" identifies failure of climate change mitigation and adaptation as one of the top five global risks, in terms of both likelihood and impact. On the verge of the climate tipping point, humans have no choice but to organize their economic activity more thoughtfully so that economic progress and conservation of the natural world can go together (Heal, 2017). Carbon pricing approaches (market mechanisms such as carbon taxes and cap-and-trade regimes) are, in fact, economic tools that economists hope could help us move away from burning fossil fuels. They are intended to mitigate the consequences of global warming before it becomes too late.

Addressing climate change, the greatest external effect in human history in Heal's (2017) terms, is a complex issue as it involves at least three difficult problems (Henderson et al., 2018): discount rates, free riding, and global geopolitics. Given the fact that the benefits of addressing enhanced GHG emissions almost certainly outweigh the costs – and that the effects of increased emissions remain in the atmosphere for so long and affect the welfare of future generations – still a concerted global action to solve the problem is not easy. Who should pay for responses to climate change, and how much should be spent are the matters of ongoing debate. Despite the ongoing debate on these issues, the international community has agreed upon so far that shaping behavior through market mechanisms are the most effective ways to reduce GHG emissions. Kyoto Protocol, adopted in 1997 and taking effect in 2005, was the first attempt to implement a global cap and trade system.

Economics of Emissions Reduction

A central insight in microeconomics – known as Coase theorem – is that if nothing stops people from trading, buyers with high marginal benefits and sellers with low marginal costs continue trading until all potential gains from trade are exhausted (Coase, 1960). In other words, in the absence of government intervention, free exchange tends to move resources to their highest valued use, which in that case the allocation of resources is said to be Pareto efficient (Cooter, 1989).

Competitive markets, nonetheless, do not always perform so miraculously. Particularly, when the side effects (externalities) of an economic transaction positively or negatively affect those not directly involved in the transaction, market outcomes are not efficient anymore (Goodwin et al., 2014). In the case of negative externalities (pollution is a classic example), government can regulate the side effects by imposing taxes (which in case of pollution they are called Pigouvian taxes) on polluting products. Pigouvian taxes are, in fact, economic coercion, or persuasion, measures for firms to reduce pollution (Pigou, 2002); firms are expected to do so as long as the marginal cost of the reduction is lower than the tax (Pearce, 1991; Nordhaus; 1991; Fay et al., 2015).

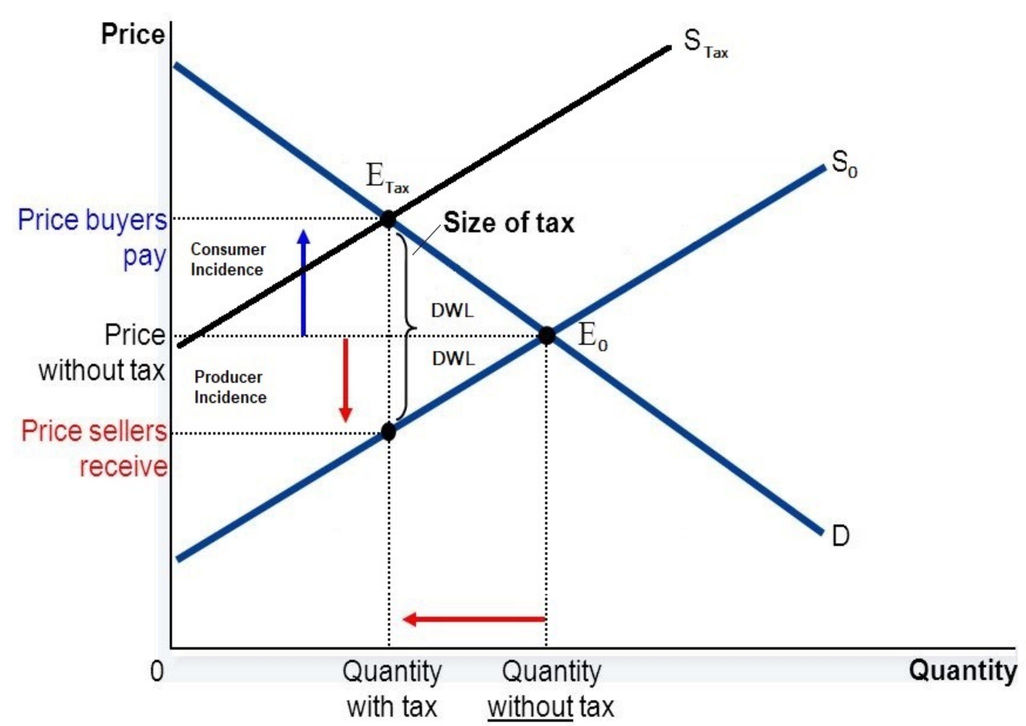
Another policy option is tradable pollution permits, which is practically identical to Pigouvian taxes although they sound different from each other. Other approaches to environmental regulation are setting pollution standards, and incorporating pollution-control technologies. Nevertheless, most economists have agreed upon the former two policy options (Pigouvian taxes and tradable pollution permits) as the most effective market-based approaches to internalize negative externalities, especially when they are carbon emissions. In the next section of the paper (Policy Instruments to Reduce GHG Emissions) pollution taxes and tradable permits (also known as cap-and-trade) will be compared and contrasted. Government intervention in the market also make sense in the case of positive externalities. A good example of such externalities is solar panels.

This section of the paper begins with the welfare analysis of an excise tax which represents the effect of government intervention in the absence of externalities – the ideal situation of perfect competition. The analysis depicts that in the heavenly world of perfect competition, a market regulation such as an excise tax results in the reduction of social welfare. The section continues with the formal analysis of negative externalities, first without and then with a Pigouvian tax, to highlight the role of government intervention when the side effects of an economic transaction negatively affect other economic units; thus, making the market outcome inefficient. As it will be illustrated, in the presence of negative externalities (e.g., pollution) in the market, regulation seems to be quite reasonable because it increases social welfare. Market regulation in the case of positive externalities (e.g., solar panels) will also be briefly discussed, and it will be shown why a common policy recommendation in the presence of a positive externality is to subsidize the product to encourage greater production.

Welfare Analysis of Taxation

According to Goodwin et al. (2014), even common sense is enough to predict what will happen to consumer and producer surplus as a result of levying an excise tax on a product. It seems reasonable, he says, to expect that both decline. When a tax is imposed on a product, the difference between a consumer's maximum willingness to pay and the higher price decreases. Also, in a similar way, the difference between the selling price of producer and the marginal costs of its product drops.

Figure 1. Welfare Analysis of an Excise Tax



Source: Modified from Goodwin et al. (2014). *Microeconomics in context* (Third Edition.). Armonk, New York : M.E.Sharpe,. , p. 245.

A welfare analysis, as Goodwin et al. (2014) assert, should consider the impacts of a market on the rest of society as well. Figure 1 depicts the welfare analysis of an excise tax. As shown on the diagram, the supply curve shifts to the left as a result of imposing a tax on a given product. There is no tax revenue in the market before regulation. Therefore, the social welfare at market equilibrium (E_0) is equal to the sum of consumer and producer surplus. At the new market equilibrium denoted by E_{Tax}, however, a smaller amount of the product is manufactured at a higher price.

As illustrated, after government intervention both the consumer and producer surplus shrink to provide tax revenues to the society at the expense of imposing a deadweight loss equal to the areas denoted by DWL. After the regulation, levying the tax, total social welfare comprises tax revenues as well as consumer and producer surplus. But, the sum of these three components are smaller than the sum of consumer and producer surplus at the market without taxation. This analysis shows that in the ideal situation of perfect competition (in the absence of the cases of market failures particularly externalities), a market regulation such as an excise tax results in the reduction of social welfare while the reduction equals the potential gains from trade (DWL areas in the figure) that the market no longer exploits for producer and consumer.

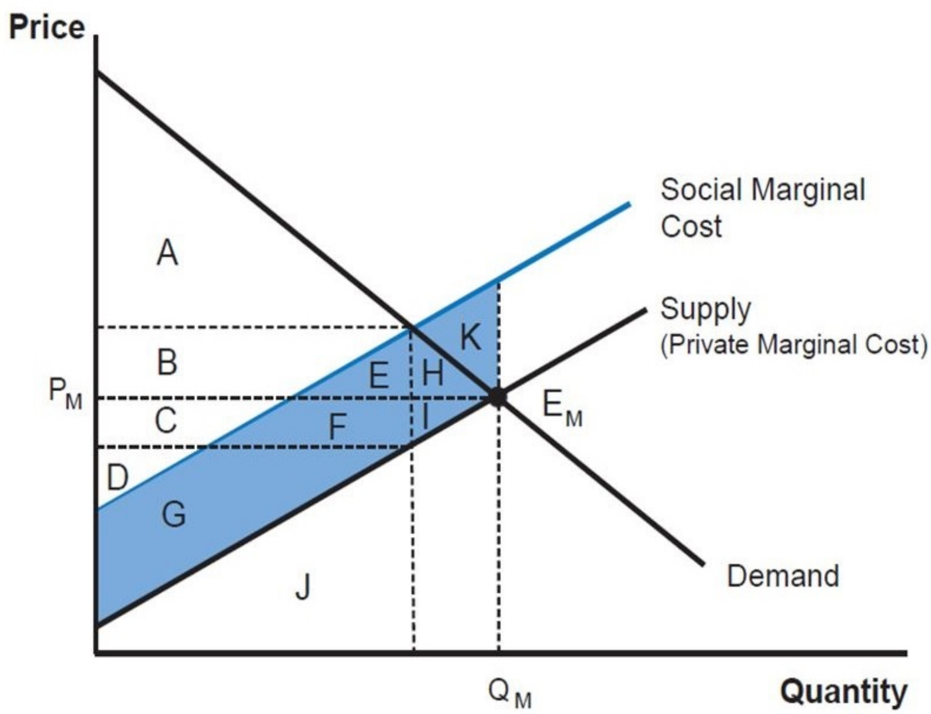
Welfare Analysis of Negative Externalities

Unlike an excise tax which results in the reduction of social welfare, a Pigouvian tax clearly makes society "better off" (Goodwin et al., 2014). In the presence of a negative externality in a market, in fact, the market outcome is inefficient. But, levying a pollution tax internalizes the externality for polluters; thereby, making social outcome efficient. Below are provided two other scenarios of analyzing social welfare. In these scenarios, in the presence of a negative externality, first social welfare is analyzed without a Pigouvian Tax, and then it will be analyzed with a tax on the polluting product.

Analysis of a Negative Externality, without a Pigouvian Tax

When a product generates negative externality in a market, as Goodwin et al. explain, social welfare includes three components: consumer surplus, producer surplus, and externality damages. Obviously, while the externality damages decrease social welfare, the former two contribute to it. Figure 2 depicts each of these effects. In the case of a negative externality the social cost of providing a good exceeds the private costs (Chiang, 2013); such an externality, therefore, can be represented in a supply-and-demand graph (see the figure 2) as an additional marginal cost. In the figure, which illustrates the market without any regulation, E_M denotes market equilibrium; consumer surplus (defined as the difference between a consumer's maximum willingness to pay and the market price) is shown by the area above the price but below the demand curve; producer surplus (the difference between the equilibrium price and the marginal costs of the product) is depicted by the area below the price and above the private marginal cost curve; and finally externality damages are represented by the shaded area between the supply and social marginal costs. As Goodwin et al. (2014) clarify, in case of a negative externality, the net social welfare of the unregulated market (without a Pigouvian tax) equals the following sum: A + B + C + D – K.

Figure 2. Welfare Analysis of a Negative Externality, without a Pigouvian Tax

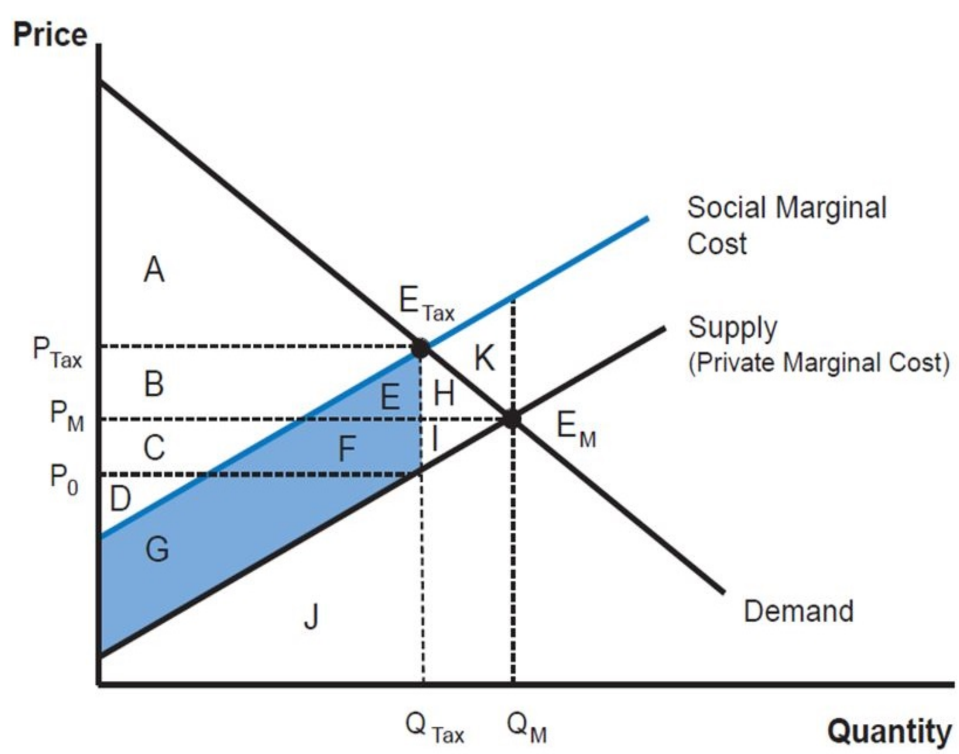


Source: Adopted from Goodwin et al. (2014). *Microeconomics in context* (Third Edition.). Armonk, New York : M.E.Sharpe,. , p. 281.

Analysis of a Negative Externality, with a Pigouvian Tax

As explained by Goodwin et al., nonetheless, in the presence of a negative externality the net social welfare can be improved by the imposition of a pollution tax. See figure 3.

Figure 3. Welfare Analysis of a Negative Externality, with a Pigouvian Tax



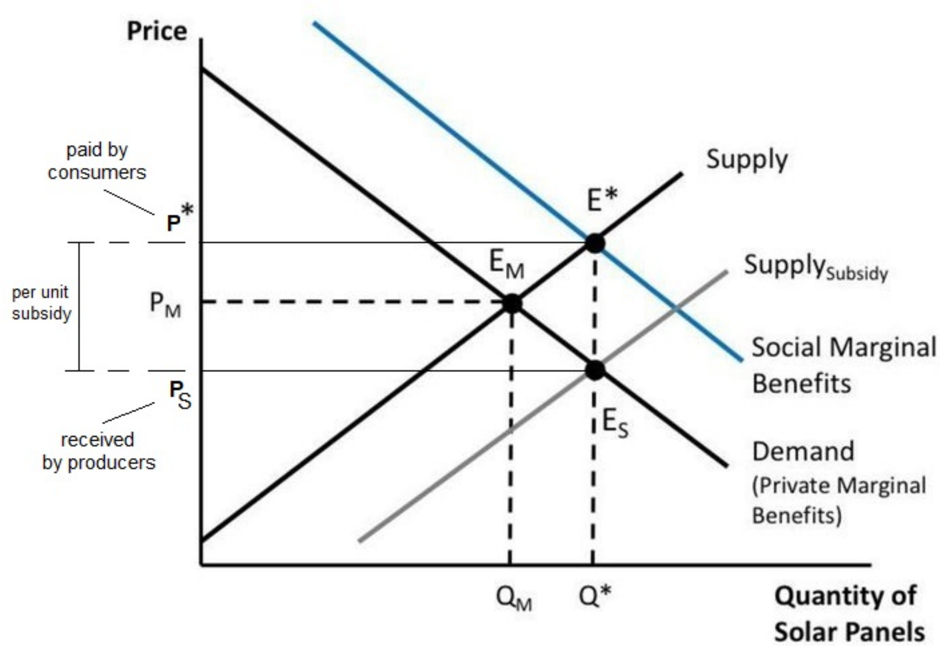
Source: Adopted from Goodwin et al. (2014). *Microeconomics in context* (Third Edition.). Armonk, New York : M.E.Sharpe,. , p. 282.

With a Pigouvian tax, the quantity of production falls to Q_{Tax} in response to the rise of the price to P_{Tax}. In other words, the regulated market equilibrium forms at a lesser quantity of production and a higher price – which is equal to the sum of marginal and social cost for each unit of production. Now producers and consumers share the burden of the tax revenues that are generated while consumers' share of the burden (consumer incidence) is not necessarily equal to producers'. Goodwin et al. also emphasize that revenues are exactly equal to externality damages (equal to E+F+G, in the figure). Also, like the case of an excise tax, in this case as well a deadweight loss (equal to H+I) seems to be imposed to market participants. Nonetheless, overall in this case the net social benefits increases; although H and I are subtracted respectively from consumer surplus and producer surplus, the society has in fact has avoided the negative impacts of "too much" production depicted by area K. With a pollution tax, total social welfare is comprised of four components: consumer surplus, producer surplus, tax revenues, and externality damages. The net benefits (social welfare) equals the sum of A, B, C, and D; in that, benefits have increased by the amount of K as a result of the Pigouvian tax.

Welfare Analysis of Positive Externalities

Market regulation also make sense in the case of positive externalities (e.g., solar panels). As Goodwin et al. explain (see figure 4), a positive externality can be considered as an additional marginal benefit gained by society, beyond the private benefits of consumers. In the presence of positive externalities, therefore, an unregulated market outcome would be inefficient; for example, too few solar panels are manufactured if greater production would not be subsidized by the government.

Figure 4. Analysis of a Positive Externality



Source: Modified from Goodwin et al. (2014). *Microeconomics in context* (Third Edition.). Armonk, New York : M.E.Sharpe,. , p. 264.

In sum, an excise tax results in the reduction of total social welfare as it imposes a deadweight loss to the society; apparently a gain that no one gets, to make the market outcome inefficient. However, externalities are prominent examples of market failure. Negatively or positively when they affect a market, government intervention seems to be necessary to achieve a socially efficient outcome. Particularly, when there is a negative externality in a market (e.g., a polluting product), the imposition of a tax certainly makes society better-off. Also, in the case of positive externalities (such as solar panels), subsidies could encourage greater production, thereby, resulting in the increase of overall social welfare.

This section of the paper, in fact, provided rationale for the following quotation from the prominent PBS commentator Bill Moyers:

> "If you want to fight for the environment, don't hug a tree; hug an economist. Hug the economist who tells you that fossil fuels are not only the third most heavily subsidized economic sector after road transportation and agriculture but that they also promote vast inefficiencies. Hug the economist who tells you that the most efficient investment of a dollar is not in fossil fuels but in renewable energy sources that not only provide new jobs but cost less over time. Hug the economist who tells you that the price system matters; it's potentially the most potent tool of all for creating social change." (Goodwin et al., 2014; page 261)

The Tragedy of The Commons:
A Generalized Prisoners' Dilemma

It is the time now to further examine greenhouse gas emissions reduction from the broader viewpoint of the tragedy of the commons. In economics, common-pool (common property) resources are defined as the goods that are nonexcludable and rival; that is, they can be freely consumed by all people, but their use by one individual reduces their availability to others. Particularly, regarding the Earth atmosphere as a common property, literally anyone can enjoy it; however, since we live in a full world economy, each individual polluter in fact diminishes the availability of fresh air to others.

Recall this quote from Hardin (1968): "Freedom in a commons brings ruin to all." According to him, valuable common property resources would be overharvested. Overharvesting common-pool resources, as Klein and Bauman (2010) clarify, can be explained in the framework of the most famous simultaneous-move game in economics: the prisoners' dilemma, a paradox in decision making with the following salient features: 1) Acting based on self-interest, each player makes their decision disregarding the choices of other players; 2) The players' dominant strategies make them all worse-off.

Climate change, or the greatest negative externality in human history according to Heal (2017), is the consequence of global warming – which is in turn a prominent example of a generalized prisoners' dilemma. Since World War II, economies have been growing exponentially, neglecting natural capital. Economy of scale has endowed humans with cheap electricity, gasoline, and fertilizers; but also, rising sea levels. As a result of the unrelenting injection of carbon dioxide to the Earth atmosphere, the Earth's inhabitants are facing now perhaps the worst tragedy of the commons ever; IPCC's most recent scientific reports provide compelling evidence that the global economy, as emphasized by Victor (2010), is testing the limits of the biosphere. This case of prisoners' dilemma in a large scale – with millions of players worldwide – help us realize how sometimes entire economies might collapse, and how abandoning nature might endanger our prosperity.

Solving The Tragedy of The commons

Recall that according to Coase theorem if nothing stops people from trading, buyers with high marginal benefits and sellers with low marginal costs will continue trading until all potential gains from trade are exhausted. Klein and Bauman (2010) assert that this theorem can solve the prisoners' dilemma if the players of the game can negotiate an agreement; that is, negotiated agreements can also solve the tragedy of the commons. In other words, players need to consider others as well in their decision making; finding a way to align their own individual incentives with the goals of the group as a whole. To clarify this, Klein and Bauman (2010) provide an interesting example: Suppose that injecting steroids has become a dominant strategy of athletes. So, everybody wants to have the most powerful muscles even if the drugs might make them all bald and impotent. This is another case of the prisoners' dilemma, resulting in the tragedy of the commons. In this case, a negotiated agreement to solve the tragedy could be the submission of steroid testing to ban the sportsmen who fail. Remember this quote from Hardin (1968): “Conscience is self-eliminating”.

In contrast to futile reliance on the conscience of individuals to control their behavior, negotiated agreements work to legislate temperance; as Hardin says, coercive (or persuasive) measures make bad behavior increasingly more expensive for the wrongdoer, and this is more effective than prohibition. Ostrom (2008) provides another example of successful coercive measures. In response to the problem of overharvesting fisheries, she refers to negotiated agreements (between local fishers and state officials) and mutual coercive measures that give effective protection to juvenile lobsters and proven breeding stock as well as limit the number of lobster traps. She says, and I quote, “These rules enable lobster fishers to monitor each other’s harvesting with substantial effectiveness.”

Using a tradable permit system to keep fisheries sustainable, and levying taxes on fossil fuels to prevent rising sea levels are other examples - provided by Klein and Bauman - that reveal how negotiated agreements might help solve the tragedy of the commons. Ostrom also underlines the importance and effectiveness of quotas determined based on active dialogue while she criticizes the Hardin’s conclusion of an inevitable tragedy [in case of common-pool resources] as “too sweeping”.

Using quotas in managing the harvest of common-pool resources such as fisheries, or the Earth’s atmosphere (when it comes to global warming and climate change) is kind of a “coercion device” in the words of Hardin. From the viewpoint of economics, tradable pollution permits perform roughly the same as carbon taxes. These market mechanisms are, in fact, different means to the same end: curbing carbon emissions and generating revenue for governments to put to good use.

Concerning the application of market-based approaches to regulate pollution, although no international regime that includes all countries has been implemented yet, the international community has taken a variety of approaches at multiple levels (Ostrom, 2008). Carbon taxes and tradable permits – also known as cap-and-trade regimes – both are intended to shape the behavior of polluters by making polluting increasingly more expensive. As regards to global warming and climate change, this policy responds appropriately to the question of Hardin about the unavoidable tragedy of the commons: “How to legislate temperance?” Policy makers can use carbon pricing approaches to make laws that shape the behavior of economic units by providing incentives, rather than prohibition.

The economic rationale behind carbon taxes and tradable pollution permits is internalizing negative externalities. In Endangered Economies, Heal (2017) refers to the sound logic of making polluters pay the full cost of their actions, as the main solution to climate problem. According to him, there is no fundamental conflict between environment and economy; in that, these are market failures and unpaid-for externalities that we are suffering from. To bring a reconciliation between economic progress and conserving nature, he strictly recommends internalizing external costs, respecting property rights, valuing natural capital, and choosing the right way of measuring our economic performance (finding a replacement for GDP that more accurately reflects what matters to society). These four aspects are not separate from each other. All pivot around a central point: making polluters pay via full cost accounting.

Towards Sustainability: Valuation of Critical Natural Capital

In the context of sustainability and wealth of nations, Heal divides up the natural capital of nations into two categories: first, part of natural capital that communities can compensate for its depletion by investing in other forms of capital; second, the other category which provides to us essential services that cannot be replaced. He clarifies that the former (mineral resources such as oil and gas reserves) just gives its owners the advantage of generating wealth in the market; and it can be replaced with physical, financial, or intellectual capital. In contrast, the latter (living natural capital including forests, coral reefs, and ecosystems as examples) is more than just wealth; the loss of which cannot be compensated for and might jeopardize the human future. Oxygen and food are two specific examples of essential services that the latter type of natural capital provides to humans. In Heal's (2017) words:

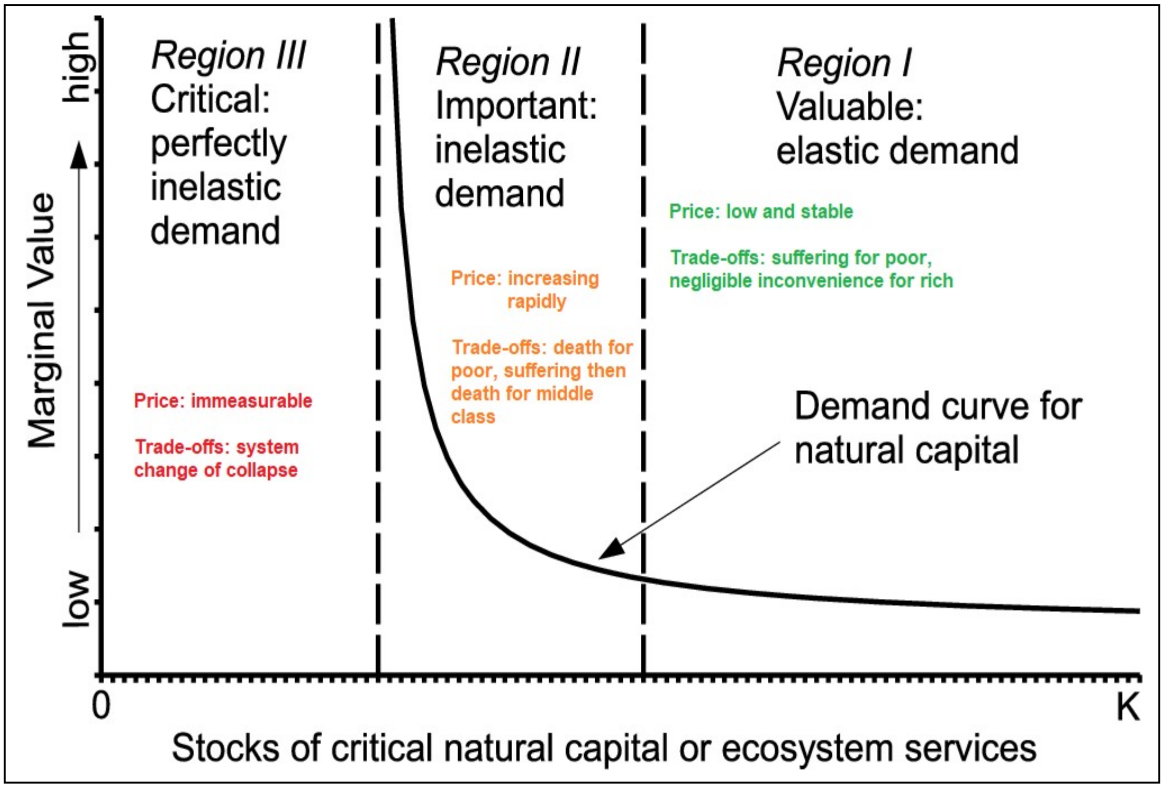
> "Oxygen is produced by photosynthesis, carried out by plants and by photosynthetic algae in the oceans, and we can't replace them. Food is also something whose production depends on the services of natural ecosystems: it depends on the productivity of soil, a complex ecosystem easily damaged by overuse; on the climate, determined in part by the complex worldwide carbon cycle; and on the actions of agricultural pests that attack food crops and their natural predators, such as birds and bats, that keep them under control."

Nonetheless, functioning markets have paradoxically resulted in questionable outcomes regarding the valuation of natural capital (Farley, 2008; Vardon et al., 2016; Heal, 2017). As they work at the moment, markets value mineral resources highly (particularly oil); but not forests, coral reefs, and ecosystems.

The reason behind this paradox, as Heal explains, is that the essential services provided by living natural capital (e.g., oxygen) are mostly public goods which makes it problematic to capture their value in the market. Public goods are nonexcludable and nonrival (Goodwin et al., 2014); in that, while their benefits are freely available to anyone, their use by one person does not diminish its usefulness to others. Moreover, Heal asserts that natural capital is often a common property. Recall that common property resources are those goods and services in economics that are nonexcludable and rival; that is, they can be freely consumed by all people, but their use by one individual reduces their availability to others. In a full world economy that we are living now (Victor, 2010), the Earth atmosphere is a common property as well because each individual polluter in fact diminishes the availability of fresh air to others. As Heal emphasizes, particularly the Earth atmosphere, and common-pool resources in general, are hard to conserve. Recall this quote from Hardin (1968): “Freedom in a commons brings ruin to all.”

Now the question is how living natural capital can be valued and protected? Farley (2008) highlights the role of prices in conserving critical - or living - natural capital (CNC) as follows. While he points out biodiversity loss and climate change as the major threats to CNC, first he underlines the fact that the valuation of natural capital may be difficult as we do not know exactly what elements of natural capital are critical. Nevertheless, he delves into the fundamental concept of “marginality” in conventional economics to explain his conceptual framework for the valuation of natural capital stocks. See figure 5.

Figure 5. Stocks of Critical Natural Capital or Ecosystem Services



Source: Modified from Farley, J. (2008). The Role of Prices in Conserving Critical Natural Capital. *Conservation Biology* 22(6): 1399-1408. , p. 1405.

Adopted from the seminal paper of Farley, this figure illustrates a hypothetical demand curve for natural capital that becomes critical beyond an uncertain limit. In region I where natural capital is intact and resilient, the demand is elastic making marginal values insensitive to small changes in stocks. Monetary valuation (the way conventional economics works), may help allocate resources between conservation and conversion in this region. In region II, as capital stocks are less resilient and approach a limit – towards a full economy which is testing the limits of the biosphere as being warned by Victor (2010) – price increases rapidly; the demand curve turns inelastic and marginal uses become increasingly important. Here Farley suggests that "conservation needs should determine the supply of the stock available for conversion and hence the price". In region III, capital stocks have passed ecological limits; price becomes immeasurable and the system collapses.

> "As global natural capital stocks come dangerously close to critical thresholds, we must learn how to solve the macroallocation problem. Monetary valuation attempts to estimate the marginal values of environmental benefits, then internalize them into market decisions to determine how much conservation and restoration is appropriate. This approach may be appropriate when we are far from critical thresholds, but under current circumstances, we should frequently adopt an opposite approach: To slightly paraphrase Daly (2007), conservation needs should be price determining rather than price determined." (Farley, 2008; page 1406)

To value CNC appropriately, as Farley clarifies, firstly we must keep or restore enough ecosystem structure to sustain vital services; then, "surplus" supply would be available for conversion to man-made products. The intersection of this supply with economic demands will determine prices for ecosystem structure. So, the proper order is: first meeting sustainability requirements, and then using valuation to improve efficiency. The way that conventional economics works (the paradigm of economic growth), nonetheless, is quite contrary to what is should be. Valuation, Farley emphasizes, can inform sustainability if conservation would be price-determining, not price-determined.

Farley also asserts that, in a full world economy we live in today, estimating thresholds for CNC is much more important than assessing marginal values. Furthermore, as he emphasizes, facing future uncertainties science will not be enough: “we must also be guided by our moral obligations to future generations.”

Policy Instruments to Reduce GHG Emissions

A Review of Market-based Approaches

GHG emissions come from goods and services that humans produce and consume. The market of such goods and services, nonetheless, fails to account for the emissions; in that, they have impacts that are not priced as a production cost. This represents a market failure. Economists suggest that the simplest and least expensive way to correct the market failure, and reduce the amount of CO_2 being dumped into the atmosphere, is to put a price on carbon emissions in order to internalize external effects. Today, the idea of providing incentives to reduce GHG emissions and making polluters pay seems to be reasonable and, from the standpoint of the theory of economics, doable. Increasingly governments/jurisdictions are introducing carbon taxes or institutionalizing cap-and-trade regimes that improve market efficiency. Evidence shows that carbon pricing reduces emissions, stimulates Innovation, and raises revenues that can be recycled back into the economy.

The economic rationale behind market-based approaches to pollution regulation is internalizing negative externalities; in that, polluters pay the full cost of their actions. According to Goodwin et al. (2014), for example when producers of a polluting product must bear a pollution tax, or a Pigouvian charge on pollution, more expensive than the marginal cost of reducing it, they will be motivated to curb pollution and continue this reduction as long as the marginal cost of pollution reduction is lower than the tax.

Nevertheless, since different firms use different technologies, their responses to the tax will not be similar. In other words, for each firm in the given industry, the amount of pollution reduction depends on the shape of its MCR (marginal cost of reducing) curve. But, each producer's response to the Pigouvian charge is cost effective; in that, it reduces its level of pollution to an amount that any other level of pollution would impose higher costs to the firm. Maintaining that all firms behave in such a cost-effective manner, the total cost of curbing pollution in the industry is minimized. Cost-effectiveness in pollution reduction is one of the main advantages of market-based approaches in contrast to pollution standards or technology-based approaches that mandate firms to take specific actions.

As a result of carbon levies, not only do producers become more efficient by adopting higher efficient technologies, but consumers reduce their amount of fossil fuel consumption. Moreover, revenues gained from pollution taxes can be used to fund environmentally beneficial projects, reduce income or employment taxes and, in a nutshell, help society adapt to climate change. (Aldy, 2017)

A cap-and-trade regime is nearly identical to a carbon tax. As Heal (2014) emphasizes, this approach also performs based on the polluters pay principle. It establishes liabilities, as well, for the consequences of external costs. Cap-and-trade schemes pivot around the basis of institutionalizing the right to pollution; in that, governments set limits on CO_2 emissions and issue permits or allowances. Then polluting firms are expected to submit, for instance, one permit per each ton of CO_2 that they release to the atmosphere. The total number of allowances is capped and over time it is reduced. The market price for emissions, then, is expected to rise as the total number of allowances is reduced.

Each issued allowance is in fact like a Pigouvian charge on pollution. Again, in this case (like a carbon tax), producers with lower MCR curves (who can reduce their pollution more effectively) have competitive advantage. In the case of a carbon tax such firms save money by not paying the tax because they could diminish their pollution to an optimum level. With a cap-and-trade regime, such innovative companies can sell their extra permits to producers who need more allowances due to their higher MCR curve or their intention to expand their business, etc. In other words, just like the case of a carbon tax, in a cap-and-trade regime as well, the cutback in emissions occurs in firms whose abatement costs are the lowest. The most innovative companies faced with carbon taxes reduce their pollution to refrain from paying the tax. Such firms under cap-and-trade regimes cut their emissions in order to avoid buying permits or even get some gains by selling their extra ones.

Since 1970s tradable pollution permits have been kind of an anathema to some environmentalists who, as Heal (2014) explains, questioned how we could combat pollution by authorizing the right to pollute? Also, in contrast to direct regulation approaches and carbon taxes, pollution permits are perceived as too complex by some politicians. Nonetheless, from the viewpoint of economics, the two approaches are roughly the same in terms of performance. In the case of tradable pollution permits, as Heal clarifies: “If we can adjust the supply of allowances so that their price reflects the external cost of the pollution, then we have internalized the external cost, which should produce an efficient outcome." This is exactly what a Pigouvian tax does.

Tradable pollution permits, nonetheless, originate from the Coase theorem. Ronald Coase, according to Heal, attributed external costs to poorly defined property rights. Recall from the application of Coase theorem that negotiated agreements could solve the tragedy of the commons. When the tragedy of the commons has led to pollution, it seems that putting a cap on pollution, and then let market participants trade available pollution allowances can lead to a socially efficient outcome at the lowest overall cost. Tradable permits, therefore, can be considered as tradable rights; the rights that are well defined, respected, and then allowed to be traded. Carbon taxes and cap-and-trade regimes reach the same point from two directions: the former from the Pigou's proposal and the latter following Coase theorem.

Carbon Taxes vs Cap-and-Trade Regimes

Price-based carbon taxes and quantity-based cap-and-trade regimes, if being appropriately implemented, can solve the pollution problem and save the planet Earth. They have an appealing side effect as well (Klein and Baumen, 2014): the revenues gained from Pigouvian taxes, or [auctioned] cap-and-trade schemes as clarified by Goeree et al., 2010), can be put to good use in society. Compared to direct regulation policies that dictate firms to take specific actions (Barker and Crawford-Brown, 2015), both approaches can result in a given level of pollution reduction at the lowest overall cost (Goodwin et al., 2014). Nevertheless, the two approaches differ from each other in some respects (Heal, 2017). They have different administrative costs, for instance. Also, they differ from each other from the viewpoint of degree of uncertainty. Below the two counterparts are compared and contrasted from different perspectives.

The first and foremost aspect of comparison that comes to mind regarding the two carbon pricing approaches is their different degrees of uncertainty. According to Heal, with carbon taxes firms are certain about the cost of emissions; thus, making decisions on long-term investment easier. But, the amount of pollution reduction is unknown to policymakers in this case. On the contrary, tradable pollution permits gives policymakers confidence regarding the amount of pollution; at least from the theoretical perspective, institutionalizing a cap for pollution reduction means that governments determine the amount of emissions reduction. Nonetheless, unlike carbon taxes, cap-and-trade regimes make investment planning difficult for firms due to the following reasons: first, the price of permits is not predictable; second, the price is volatile; third, the allocation of too many permits (in [grandfathered] cap-and-trade schemes) prevent the system from working appropriately.

The amount of pollution reduction is unknown in case of carbon taxes simply because policy makers are not aware of the MCR curves of firms; consequently, they must raise taxes during the time to meet their desired target pollution reduction. In fact, carbon taxes start working (i.e., helping reduce pollution) when taxes are raised to an optimum level; high enough to signal polluters the profitability of long-term abatement. From the administrative perspective this might be possible, but it is unpopular from the political point of view; mainly because a huge number of consumers (as well as producers) bear the burden of raised taxes and, as Barker and Crawford-Brown (2015) claim, people respond more to prospective [short-term] losses than to [long-term] gains.

On the other hand, although the amount of pollution reduction is defined by governments in cap-and-trade regimes, these systems do not usually work as expected: in that, pollution reduction does not occur unless the cap would be so tightened as to keep permit prices high enough to signal polluters to react properly. In other words, while in the case of carbon taxes the trigger to reduce pollution is raising the Pigouvian tax to a working level, in cap-and-trade regimes the trigger is an enough-tightened cap that makes auctioning start.

Even though carbon taxes are politically unpopular, they are much easier to understand than tradable pollution permits. From the viewpoint of economics, tradable permits work in almost the same way as carbon taxes do. They might seem, nonetheless, a bit confusing not only to ordinary people but also to some policymakers. Much worse, cap-and-trade regimes sometimes provide to polluting firms the possibility of lobbying for free allowances. This, of course, makes tradable permits more favorable to firms than carbon taxes; especially the firms who can enjoy their lobbying power. However, the lobbying power of polluters in action prevent the whole system from working appropriately. Powerful firms may have side information that others do not. Such misinformation results in another type of market failure (Álvarez and André (2015); the cap does not work consequently. With extra permits in market, mainly grandfathered to powerful firms, the price of permits plummets to unreasonable amounts.

It is fair enough to say that factors such as the absence of a tightened cap or the problem of extra permits work as barriers to trade in unsuccessful cap-and-trade systems. Perhaps the most serious challenge of cap-and-trade regimes is how to allocate the pollution permits? According to Heal (2017), the allowances are usually supposed to be traded within a specific period; e.g., within two to four years. Also, the starting allocation and re-allocation(s) are both problematic. Furthermore, when it comes to allocation, a grandfathering approach does not generate any revenue for governments. Also, the auctioning approach in allocation, which is politically more viable, has high administrative costs and demand appropriate infrastructure; making it harder to implement compared to carbon taxes.

While grandfathered cap-and-trade systems are prone to suffer from the lobbying power of historical polluters, in auctioned regimes both the starting allocation and re-allocation(s) of allowances are problematic (Lai, 2008). Although in theory a cap can be defined in such systems reflecting the total amount of permitted pollution, determining the total number of permits (the total amount of pollutions) in practice is a daunting problem due to the difficulty of estimating critical natural capital.

Overall, it seems that carbon taxes are more transparent and easier to implement than tradable pollution permits. Comparing the positive and negative aspects of both carbon taxes and tradable pollution permits, the former (with a gradual increase in taxes) is more applicable than the latter (with a tightened cap in order to phase out the right to pollute in a controlled way). See table 1.

Table 1. Comparing Market-Based Approaches to Carbon Pricing

Carbon Taxes		Cap-and-Trade Regimes	
+	Higher degree of certainty for producers; thereby, making their decisions on long-term investment easier.	-	Firms have uncertainty about future due to: unpredictable prices, price volatility, and the allocation of too many permits
-	The total amount of pollution reduction is unknown to policymakers.	+	Institutionalizing a cap for pollution by governments or responsible authorities.
-	Politically unpopular	+	More attractive to firms and industries
-	Raising taxes periodically adds to their political unpopularity.	-	Tightening the cap to a working level that gives firms a strong signal is not easy.
+	Raising taxes is administratively possible; much easier compared to tightening the cap.	-	Tightening the cap to a working level requires the valuation of Critical Natural Capital.
+	More understandable to both public and politicians.	-	A bit confusing not only to ordinary people but also to some policymakers.
-	Starting pollution taxes? Periodical raises? Desired target pollution reduction?	-	Challenge of how to allocate the pollution permits? Starting allocation? Reallocation(s)? Grandfathered or auctioned?
+	Less administrative costs, and Lower risk of corruption	-	Auctioning allowances demands appropriate infrastructure and high administrative costs. Also, the risk of corruption is higher.
+	Less side information	-	Grandfathered systems prone to suffer from the lobbying power of historical polluters.
Overall, carbon taxes seem to be more transparent and easier to implement than cap-and-trade regimes.			

Source: Prepared by author based on (Goodwin et al., 2014; Klein and Baumen, 2014; and Heal, 2017).

The two market-based approaches to emissions reduction are roughly the same in theory; but, as Goulder and Schein (2013) assert, in practice carbon taxes are less problematic.

Unlike other types of tax (e.g., income tax or sales taxes) which, as Heal (2017) emphasizes are politically unpopular, carbon taxes can even be appealing to public if being implemented properly with gradual raises in taxes resulting in socially efficient outcomes. See table 2 in which Heal compares different externality policies including the two market-based approaches.

Table 2. Comparing Different Externality Policies

	COST	EFFECTIVENESS	TRANSPARENCY
Regulation	Bad	Good	Bad
Cap and Trade	**Good**	**Good**	**Medium**
Taxation	**Good**	**Good**	**Good**
Liability	Bad	Medium	Medium
Activism	Good	Medium	Good

Source: Modified from Heal, G. M. (2017). *Endangered Economies: how the neglect of nature threatens our prosperity.* New York : Columbia University Press. , p. 62.

Ostrom (2012) provides a great insight when she compares the logic of behind tradable quotas with what is going on in practice between local stakeholders and officials in managing fisheries as common-pool resources:

> "The sustainable remedies in practice differ from the traditional textbook solutions, so those managing resources in practice are actually using different attributes from those suggested in the literature." (Ostrom, 2012; p.80)

Carbon taxes and cap-and-trade systems also differ from each other in practice although they are roughly the same, according to the literature of economics. In action, carbon taxes seem to be more applicable than tradable pollution permits.

Global Overview of Carbon Pricing Initiatives

Carbon pricing is not new. In early 1990s, a group of European countries pioneered carbon taxes. The world's first Pigouvian taxes were launched in Finland and the Netherlands in 1990. In the former country, the pollution tax covered energy content of fuels (gasoline, diesel, light fuel and heavy fuel oil, jet fuel, aviation gasoline, coal and natural gas) in CO_2 emissions. In the latter, while the tax was introduced initially into the country's environmental tax system, it was turned later into an energy tax, which was equally divided into energy mixed tax and carbon tax. (Lin and Li, 2011)

One year later in 1991, Norway and Denmark levied carbon taxes. Although Norway imposed the tax on petroleum, mineral fuel and natural gas in 1991, it was extended in 1992 to cover partly coal and coke as well. In this country, due to the fall in the level of investments in the oil and petroleum sector, the government was made to reduce its carbon tax. Moreover, the tax was not imposed on marine transportation, aviation and electric sectors and was levied in half for the pulp and paper sectors. In Denmark a proposal was passed to impose a carbon tax in 1991 to be put into practice in 1992. This tax covered natural gas, petroleum and other mineral fuels, except biomass fuel; and included transportation, power consumption for commercial industry and household, light and heavy industries. Countries like Norway and Denmark have recycled some of the revenue back to industries. (Markandya and Lehoczki, 1994; Scrimgeour et al., 2005)

Sweden also initiated carbon levies in 1991. Lin and Li assert that the first carbon tax in this country was 250 SEK per metric ton CO_2 (equal to $44.37). Even though the tax covered all fuel oils, the rate of the existing energy tax was reduced simultaneously. As a result, as highlighted by Elkins and Baker (2001), some high energy-consuming industries such as mining industry, commercial greenhouse industry, pulp and paper production industry, manufacturing industry and electric power industry were exempted from the carbon tax.

Scrimgeour et al. provide some background data on carbon and energy tax existence and usage in above-mentioned five countries to show that Sweden generates the most revenue from carbon taxes among these European countries. See table 3.

Table 3. Carbon and Energy Taxes in Some European Countries

Countries with carbon taxes (date of introduction)	Revenues from CO_2 tax (10^6 $PPP)	Revenues from energy tax (10^6 $PPP)	% CO_2 tax revenues in energy tax revenues
Denmark (1993)	457	2905	16
Finland (1990)	436	2519	17
Netherlands (1996)	828	6990	12
Norway (1991)	323	2429	13
Sweden (1991)	1344	5140	26

Source: Modified from Scrimgeour, F., Oxley, L., Fatai, K., 2005. Reducing carbon emissions? The relative effectiveness of different types of environmental tax: the case of New Zealand. Environmental Modelling and Software 20 (11), 1439–1448. , P. 1442

Figures for 1996

Many international, national, and regional carbon tax initiatives have been implemented since 1990s. The Canadian provinces of Quebec and British Columbia are a couple of recent examples of the implementation of carbon tax initiatives. The province of Quebec led North America by applying a small carbon tax in 2007 on petroleum, natural gas and coal. British Columbia (BC) followed Quebec a year later in 2008 with a carbon tax initiative which was set to increase by $5 per year through 2012. It now sits at about $40 per ton per year. By scheduling the annual increases as much as five years in advance, consumers were sent a progressive signal that encouraged less fossil fuel use.

BC’s carbon tax covers about three-quarters of the province's total emissions (World Bank, 2018). These are generated mainly from fossil fuel combustion and include natural gas flaring. The remaining untaxed emissions largely result from industrial processes in the natural gas, smelting and cement industries that do not involve combustion of fossil fuels.

According to the World Bank’s (2018) report, British Columbia’s tax rate increased from 30 CAD (Canadian dollar) to 35 CAD per ton of CO_2 equivalent on April 1, 2018 and will continue to increase annually by CAD5/tCO2e until the rate is CAD50/tCO2e (US$39/tCO2e) in 2021. Carbon tax in this Canadian province is intended to be "revenue neutral" (Duff, 2008). By law, all revenues from the BC’s carbon tax are used to reduce personal and corporate income taxes in the province.

Carbon tax initiative in BC is proven as a successful experience. Since the tax was introduced, fossil fuel consumption has declined more rapidly in BC than any other Canadian province and over the same period BC's gross domestic product grew faster than the Canadian average.

Like carbon taxes, cap-and-trade regimes are not new. The European Union Emissions Trading System (EU ETS) is a good example of tradable pollution permits that targets heavy emitters and, as highlighted in the World Bank's (2018) report, remains as one of the largest sources of carbon pricing revenues due to its size. The European ETS has been criticized though for granting too many permits in its starting allocation in 2005. Other jurisdictions have also been exploring tradable pollution permits. China, for example, has cap-and-trade systems in operation both at the provincial and city scales. In North America, California and Quebec established a joint cap and trade system that started operating in 2013.

Like direct carbon taxation, cap and trade systems reduce emissions, encourage innovation and raise government revenue which could be used to support energy efficient infrastructure, tax code adjustments and adaptation to climate change. It has become clear in recent years that putting a price on carbon is the most effective and easiest way to reduce emissions.

Emerging Developments and New Trends

Today more national and subnational jurisdictions as well as private sector entities are adopting carbon pricing. According to the World Bank's (2018) report, to date 51 carbon pricing initiatives worldwide have been implemented or are scheduled for implementation; this consists of 25 emissions trading systems (ETSs), mostly located in subnational jurisdictions, and 26 carbon taxes primarily implemented on a national level. This trend is insufficient, however. Although the World Bank's (2018) report asserts that carbon pricing can serve multiple environmental and social objectives, there is still a long way to go to address the full external effects imposed on the planet by global warming and to reach the reality of a sustainable development path.

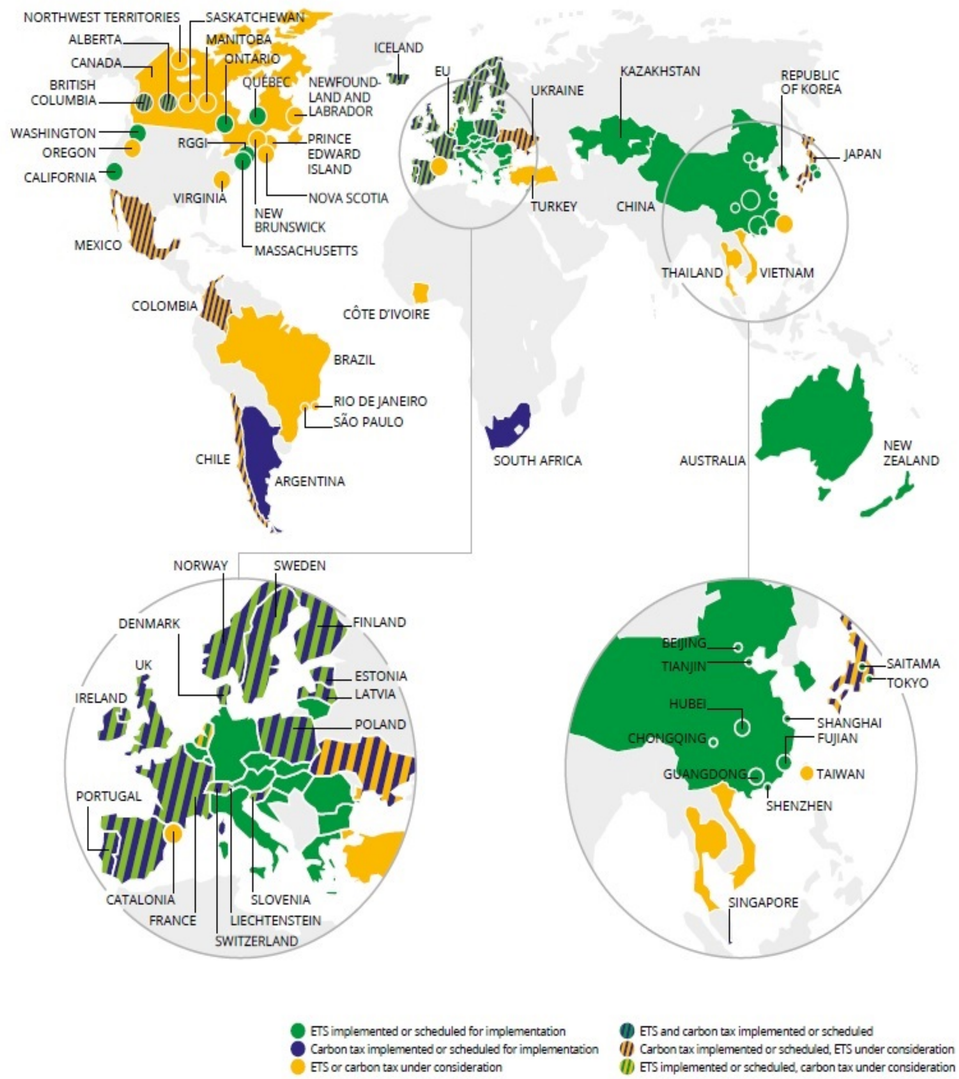
While the need to properly price carbon remains a major challenge, 85 percent of global emissions are currently not priced at all, and about three quarters of the emissions that are covered by a carbon price, are priced below US$10/tCO2e. (World Bank, and Ecofys., 2017; PMR, 2017)

Figure 6 - adopted from World Bank's (2018) report - summarizes regional, national and subnational carbon pricing (ETS and carbon tax) initiatives implemented, scheduled for implementation and under consideration.

World Bank's (2018) report also compares carbon prices, share of emissions covered, and carbon pricing revenues of implemented carbon pricing initiatives across the world. See figure 7. According to the WB's report:

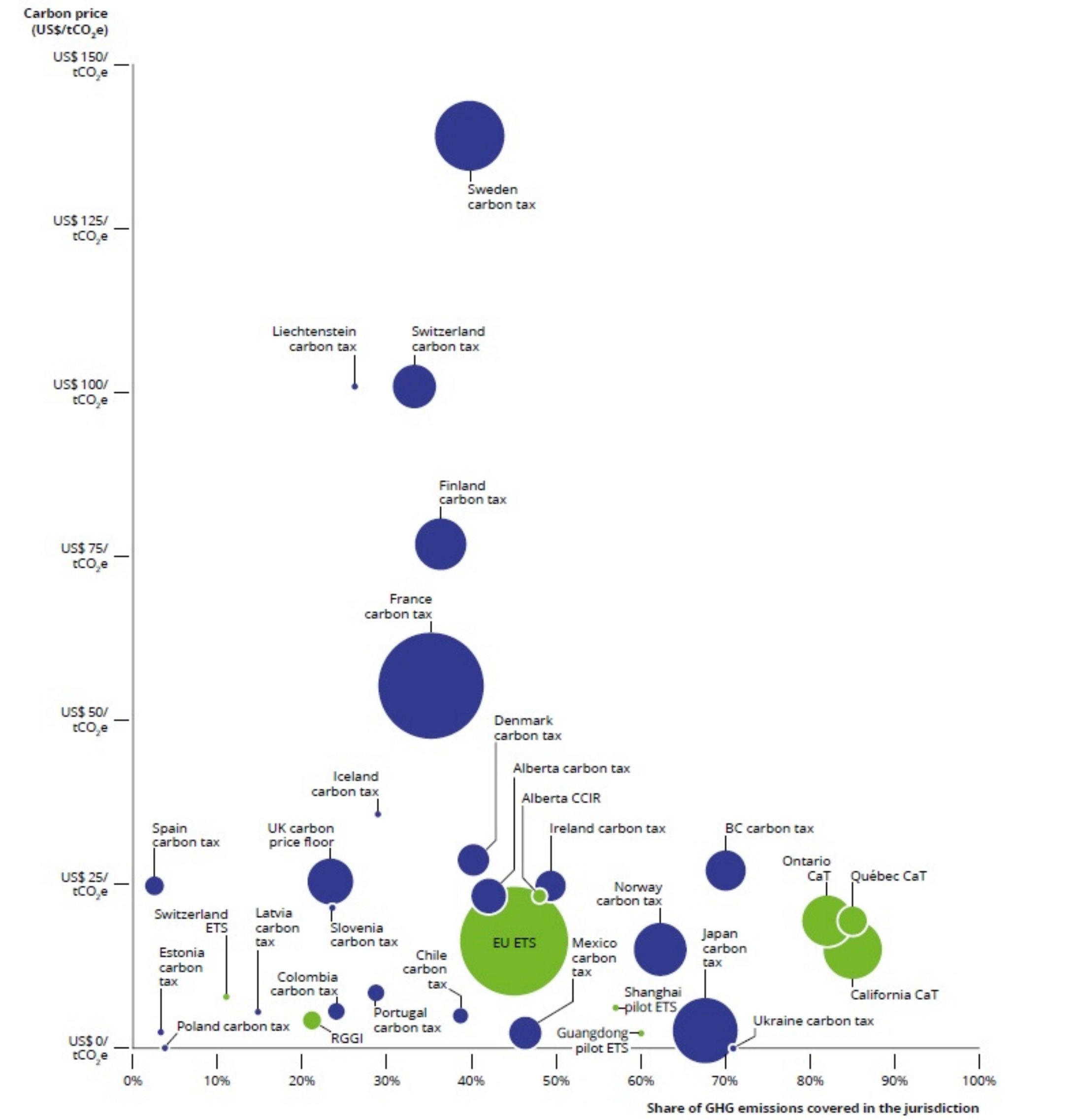
> "While some carbon prices are increasing, further rises are needed to stimulate emission reductions in line with the Paris Agreement. … Increased cooperation between governments, businesses, non-state actors, non-governmental organizations and other stakeholders can accelerate implementation and increase ambition." (World Bank, and Ecofys. 2018; p. 27-28)

Figure 6. Summary map of regional, national and subnational carbon pricing initiatives



Source: Modified from World Bank, and Ecofys. 2018. State and Trends of Carbon Pricing 2018. Washington, DC: World Bank. © World Bank.

Figure 7. Carbon price, share of emissions covered and carbon pricing revenues of implemented carbon pricing initiatives



Note: The size of the circles is proportional to the amount of government revenues except for initiatives with government revenues below US$100 million in 2017. the circles of these initiatives have an equal size. For illustrative purposes only, the nominal prices on April 1, 2018 and the coverages in 2018 are shown. The carbon tax rate applied in Mexico and Norway varies with the fossil fuel type and use. The carbon tax rate applied in Denmark varies with the GHG type. The graph shows the average carbon tax rate weighted by the amount of emissions covered at the different tax rates in those jurisdictions. The middle point of each circle corresponds to the price and coverage of that initiative.

Source: Adopted from World Bank, and Ecofys. 2018. State and Trends of Carbon Pricing 2018. Washington, DC: World Bank. © World Bank.

Pitfalls of Cap-and-Trade

Cap-and-trade regimes seem to suffer from some pitfalls in practice although they are expected to perform just like Pigouvian taxes, according to the literature of economics. The problems of the European Union Emissions Trading Scheme (EU ETS), the biggest trading pollution permits system in the world, since the year 2000 supports this claim.

Free permits in Grandfathering Allocation

The first concerted effort to develop a multinational market for carbon emissions (EU ETS) suffers firstly from free allowances (Heal, 2017). Henríquez (2013) clarifies that under the grandfathering allocation approach taken in phase I of the EU ETS implementation (2005-2008), permits have been allocated at no cost to polluting companies in proportion to their historical pollution levels. According to Heal, this approach has been, and will be, more favorable to most polluters; compared with auctioning which is better for public and government as it generates revenue. He emphasizes as well that grandfathering permits (free allowances) is criticized especially by environmentalists; they argue that it is just like rewarding companies for a history of pollution. Also, in such an oversupplied carbon market (as described by Henríquez) companies would not have economic incentives to innovate and reduce pollution.

An unfair allocation of permits makes the carbon market biased by putting most of the burden of internalizing externalities on short and medium-sized enterprises (SMEs). It seems to me that, in this case, the “Invisible Hand” of

Adam Smith would work solely in favor of historical polluters while unresolved negative externalities end in market failure. Furthermore, grandfathering does not generate revenues that can be recycled back into the economy (Cramton and Kerr, 2002; Goodwin et al., 2014; Klein and Baumen, 2014; Barker and Crawford-Brown, 2015; and Heal, 2017). As Heal points out, therefore, it is not politically saleable to public, as opposed to the auctioning approach in so-called cap-and-dividend regimes.

When it comes to choosing one of the two allocation approaches, nonetheless, both grandfathering and auctioning are the same in terms of abatement. So, the choice of how carbon should be priced in a given country could be a pragmatic decision, made on the basis of what is likely to work best there regarding its political and institutional setup (Goulder and Schein, 2013). No matter how allowances are allocated, as Heal and Goodwin et al. clarify, low-cost polluters (those with lower MCR curves) who enjoy cost effectiveness sell their unused permits to high-cost producers who need pollution permits. According to Lygre and Wettestad (2018), Regional Greenhouse Gas Initiative (RGGI), California, is the only ETS in the world that allocates most of its allowances through auctioning. Table 4 compares and contrasts the design of EU ETS with RGGI's.

Table 4. Design Overview of EU ETS and RGGI		
	EU ETS	**RGGI**
Type of system	Cap and trade Phase I: 2005-7 Phase II: 2008-12 Phase III: 2013-20 Phase IV: 2021-30 Banking allowed from Phase II on	Cap and trade Phase I: 2009-11 Phase II: 2012-14 Phase III: 2015-20 Banking but not borrowing
Ambition level	Initially no common cap 2013-20: 21% reduction by 2020 (2005)	Caps through emission budgets for each phase
Coverage	Power producers and a number of energy-intensive industries – airlines from 2012 Upstream focus ("direct" emissions) CO_2; also nitrous oxide and perfluorocarbons (phase III) Around 11,000 installations	Electricity generators larger than 25 MW in nine states Only CO_2
Allocation mechanisms	Initially mainly free allocation From 2013 on, ca 40% auctioning, to increase	Almost 100% auctioning
Revenue earmarking	From 2013, recommendation to use 50% of revenues for climate purposes	Revenues to support energy efficiency, renewable energy and direct bill assistance
Source: Modified from Scrimgeour, F., Oxley, L., Fatai, K., 2005. Reducing carbon emissions? The relative effectiveness of Wettestad, J., & Gulbrandsen, L. H. (2018). *The evolution of carbon markets: Design and diffusion.* Abingdon, Oxon ; Routledge, an imprint of the Taylor & Francis Group. , P. 250		

A System Prone to Price Fluctuation

Cap-and-trade regimes fix a cap on greenhouse gas emissions while allowing the price to vary (Fay et al., 2015). As a result, most cap-and-trade schemes have shown considerable price volatility. The price of permits, therefore, is very sensitive to demand shocks. Perhaps this is the second shortcoming of such systems. For instance, Henríquez's (2013) clarifies how the financial crisis of 2008 (occurred at the start of phase II of the EU ETS implementation) has caused plummeting permits price to low records in 2012. According to him, by the end of the compliance period in 2012, emissions dropped significantly (11.6 per cent compared with 2008) due to the slowdown in growth. Fay et al. provide another example from California as follows: "when the 2000 energy supply crisis encouraged power companies to bring back online some older and dirtier plants, the resulting increase in the demand for nitrous oxide emission allowances drove prices from $400 to $70,000 per ton in the peak month".

The low price of permits provides no incentive to curb pollution. As a matter of fact, low-cost abaters who utilize more modern technologies reduce pollution despite having permits, only if they can gain from a meaningful difference between the cost of pollution reduction and the selling price of allowances (Goodwin et al., 2014; Heal, 2017).

In my view, price fluctuations not only influence the market for permits but also are problematic concerning the important matter of conservation. If conservation of critical natural capital is fundamental to our prosperity, it is not acceptable to see a drop in permits price in times of economic turmoil. In other words, conservation of natural resources must be continuous and ongoing through ups and downs (business cycles) of the global economy.

One way to reduce price volatility, as suggested by Fay et al. (2015), is to allow for the intertemporal banking and borrowing of permits, by which companies can save extra allowances allocated to them for use in the future, or borrow from their future permits. Fay et al. points out that this approach has been partially implemented in the EU ETS, where banking is allowed without limit, and borrowing is limited to one year (to avoid depending too much on tomorrow's institutions to limit today's emissions). According to Knopf et al. (2014), other recent proposals to reduce price volatility include relying on carbon stability reserves or on price ceilings, price floors, or price corridors, beyond which the government buys or sells unlimited permits to stabilize the price.

The Problem of a Wide Cap

The third pitfall of cap-and-trade regimes is the problem of a wide cap. Although the amount of pollution reduction is determined by authorities in cap-and-trade schemes, pollution reduction does not occur unless the cap would be so tightened that keep permit prices high enough to signal polluters to act accordingly. In other words, while in the case of carbon taxes the trigger to reduce pollution is raising the Pigouvian tax to a working level, in cap-and-trade regimes the trigger should be an enough-tightened cap that makes auctioning start. Nonetheless, as Heal (2017) emphasizes, a sudden phasing out of the right the pollute is too costly; perhaps because cap-and-trade schemes are more complex to establish and more costly to administer than carbon taxes. Fay et al. clarify:

> “All countries already have a tax administration in place — and a carbon tax is mostly an extension of well-understood energy or fuel taxes — while a new institution must be created for cap and trade. Further, a carbon tax would presumably be the responsibility of the ministry of finance, making it easier for the revenues to be recycled in reduced conventional taxes. With cap and trade, the regulator must not only monitor emissions but also establish a registry for allowances and keep track of allowance trades and the associated changes in ownership of allowances.” (Fay et al., 2015; p. 84)

Due to the complexities and high administration costs of cap-and-trade systems, in all cap-and-trade schemes implemented to date, as highlighted by Heal, the cap has been progressively tightened over time; in that, the right to pollute has been phased out gradually - in a controlled way. According to him, permits are usually reallocated in periods of two to four years in cap-and-trade systems; compared to carbon taxes which can be increased annually. While an appropriate cap can guarantee conservation of critical natural capital (CNC), in action the cap in such systems is set far above its optimum level. Another reason behind an inappropriate cap is that the valuation of CNC is fundamentally a daunting problem.

Improper Method of Auctioning

Back to the first shortcoming of cap-and-trade regimes (grandfathering and excess permits), it would be promising to migrate from this approach of allocation to auctioning. According to Heal, concerning the EU ETS, the plan is to transfer from grandfathering to auctioning in subsequent rounds of permits allocation. Nevertheless, there is no guarantee that auctioning works as expected. Recall from Ostrom (2012) who says: “the sustainable remedies in practice differ from the traditional textbook solutions”. In addition, improper methods of auctioning for the rights to pollute might cause another problem with cap-and-trade regimes. This, in its turn, can be the fourth weakness point of such systems.

Would ascending auctions for the rights to pollute be wise selections? An ascending auction in pollution permits allocation means selling the right to pollute to highest bidders. I wonder if this method of auctioning works best towards solving the pollution problem and saving the planet Earth. Recall that conservation needs should be price determining rather than price determined (Farley, 2008). It seems to me that in an ascending auction, market forces (which work very effectively in conversion of natural resources into different forms of man-made products) are misguidedly supposed to determine the level of conservation.

But, as emphasized previously in Economics of Emission Reduction section (Towards Sustainability: Valuation of Critical Natural Capital), to appropriately value critical natural capital (CNC), first we must keep or restore enough ecosystem structure to sustain vital services; and then, “surplus” supply would be available for conversion to man-made capital. In fact, the intersection of this supply with economic demands will determine prices for ecosystem structure. In other words, the proper order is: first meeting sustainability requirements, and then using valuation to improve efficiency (Farley, 2008; Vardon et al., 2016; Heal, 2017).

According to Farley, in the full world economy we live in today, estimating thresholds for CNC is much more important than assessing marginal values. Nevertheless, ascending auctions seems to work more consistently with the performance of conventional economics than the conservation of CNC; consequently paying the least possible for the most valuable natural resources. Obviously, this paradigm of economic growth is quite contrary to what it should be. We know that valuation can inform sustainability if conservation would be price-determining, not price-determined.

There are different types of auctions in economics. Klein and Bauman (2010) classify them all into four categories, as follows: ascending auctions, descending auctions, 1st-price sealed-bid auctions, and 2nd-price sealed-bid auctions. Theoretically all types of auctions are expected to disclose how much something is worth, to encourage selling stuff fast, to ensure transparency (prevent corruption), and to generate the same revenue in many circumstances.

As Klein and Bauman clarify, the dominant strategy of bidders in ascending auctions and 2nd-price sealed-bid auctions are the same; in such auctions, although bidders reveal their true values in the market, the winning bidder only pays the second highest bid. In contrast, in descending auctions and first-price sealed-bid auctions, bidders follow the strategy of shading their own bids; yet, the winner pays his/her own suggested price by the end.

While according to the literature of economics different methods of auctioning would end in the same results (generating the same revenue), it seems that the performance mechanism of descending auctions suits better to auctioning the rights to pollute. While a descending auction with the most expensive starting price possible looks like more reasonable for auctioning pollution permits, a conjecture for the starting price in such an auction could be the highest implemented carbon tax ever worldwide. The question is why not?

A descending auction starts from a high price which is set by a regulator — governments or authorities in cap-and-trade regimes (Klein and Bauman, 2010). Considering the importance of conserving CNC, therefore, even a lower limit could be applied in such an auction, especially in cases of economic turmoil, in order to prevent a sudden drop in prices. It seems to me that this way of auctioning is more consistent with our conservation needs. Also, we know that a tightened cap is required for an effective cap-and-trade regime. We know as well that the tightened cap demands the valuation of critical natural capital which is a daunting task itself. Starting with a high enough permit price (equivalent to the highest implemented carbon tax worldwide) combined with objective trial and errors, tuning policies, might guide us towards an optimum solution.

Fraud and Corruption

Another pitfall of cap-and-trade schemes is the problem of carbon offsets which can undermine the efficiency and fairness of such systems. Klein and Bauman (2014) explain how a polluting firm in a rich country, for example, can buy offsets to reduce emissions in another country (a poor one like Indonesia and Brazil) rather than buying pollution permits for his/her own factory. While the former is settling GHG liabilities (paying to pollute), the latter, as clarified by Martin and Walters (2013), is to create carbon assets. Theoretically, the idea of buying offsets instead of buying allowances makes sense; firms can cut emissions through offsite projects that reduce emissions. If curbing emissions in poor countries is cheaper, the amount of pollution reduction per dollar in those countries would be even more, compared to that in the home (rich) country. However, as Klein and Bauman clarify, the devils to carbon offsets are in details; for instance, there is no guarantee that a given factory in the poor country continues cutting emissions after the receipt of fund from the rich firm/country; the polluting firm in the poor country might even be replaced next year with a dirtier factory elsewhere. See Gillenwater (2012) as well.

> "It seems that, at least on this specific issue, the emission offset community, myself included, has taken on the characteristics of a used car salesman … spouting off a term that sounds good to everyone but that does not clearly mean anything. We might as well have required that offset projects be 'beautiful' or 'synergistic' or some other vacuous buzzword that can be employed to sell an idea. You may have thought you knew what a 'real' offset project was, but … the offset community has fallen under a form of group think. What is amazing, and worthy of its own sociological study, is how we managed to go for long in our development of standards, laws, methodologies, manuals, and articles using such an ambiguous term for our fundamental concepts of offset project quality." (Gillenwater, 2012; p. 169)

Much worse than the danger of real offsets are non-existent credits; scams known as false permits. Real offset permits are created when a polluting firm allegedly cuts carbon emissions, and then it gets permits which can be sold to polluting firms that need extra permits to emit more pollution. Theoretically, but not necessarily in action, one activity offsets the other. But, a very dangerous problem occurs if real CO_2 is not being removed by the company seeking offset permits for pollution reduction. Because offset permits are worth real money, there are incentives to create false offsets; in that, earning offset permits for doing nothing.

According to Martin and Walters (2013), the media has widely alleged fraud and criticized misrepresentation in carbon markets; as if governments are deceiving people. Also, cases of actual criminal fraud in the compliance and voluntary carbon markets have come under the spotlight by the media. As Lohmann (2010) points out, the risk of carbon fraud in both the allowance markets (EU ETS) and the offset credit market has been widely reported. Quoting him: “what are conventionally classed as scams or frauds are an inevitable feature of carbon offset markets, not something that could be eliminated by regulation targeting the specific businesses or state agencies involved”.

Some analysts like Goulder and Schein (2013), nonetheless, believe that cap-and-trade systems’ potential difficulties with offsets do not constitute a weakness of such schemes relative to carbon levies. They assert that offsets are not an inherent feature of cap-and-trade; in other words, one can include or exclude offsets from such systems. Moreover, just as with cap-and-trade, it is possible to include or exclude offsets as part of a carbon tax program. To clarify this, they provide two examples: South Korea's proposed cap-and-trade program which bans the use of international offsets, and New Zealand's cap-and-trade program allowing unlimited use of offsets.

Martin and Walters attribute the most continued critiques of carbon credit fraud risk to NGOs such as Transparency International (2011), Global Witness in their report "Forest Carbon Cash and Crime" (2011), and Greenpeace's "Carbon Scam" (2009). According to them, reports like these not only question the genuineness of carbon credit schemes, but indicate that "the lobbying power exerted by the powerful participating companies and the relative weakness of the regulatory structure gives rise to form of carbon fraud or "scam" at the global level". Table 5 represents the types of carbon crimes reported by the media, police agencies and NGOs.

Table 5. Typologies of Carbon Crimes

Typology	**Crime risk**	**Markets affected**
Computer crime	Internet phishing, cyber theft	Allowances, EU ETS
State crime	Recycling of carbon instruments	Allowances, EU ETS
Taxation crime	Missing-trade fraud (MTF)	Allowances, EU ETS
Scams	Investment scams, fake carbon credits, Ponzi schemes	Carbon credits for voluntary market
Corruption and bribery	Falsifying records, fake offset schemes, pressure on local people	Carbon credits for voluntary and compliance market
Structural fraud	Fraud risk through poor incentive structure, inadequate validation and verification	Carbon credits in for compliance markets

Source: Modified from Martin, P., & Walters, R. (2013). Fraud Risk and the Visibility of Carbon [Text]. https://doi.org/10.5204/ijcjsd.v2i2.95 , P. 30

Carbon fraud can indicate wider systemic properties of carbon marketisation that are inherently fraudulent (Bachram, 2004) and corruptible (Lohmann, 2010); and this, as emphasized by Martin and Walters (2013), connects with concerns of NGOs. Critics like Bachram and Lohmann argue that the way such incentives are structured creates an essentially unregulatable market. Also see Lindquist and Goldberg (2010).

Finally, Leonard (2009) in “the Story of Cap and Trade” points out that while free permits and offsetting make cap-and-trade schemes unfair and ineffective, it would be a perilous distraction if such systems create a false sense of progress towards cutting emissions, or weaken our ability to make strong laws.

To learn more about “what is working, what isn’t and why, when it comes to the practice of implementing an ETS”, see Narassimhan et al. (2018). This article compares eight ETS regimes worldwide against five main criteria: environmental effectiveness, economic efficiency, market management, revenue management and stakeholder engagement.

Discussion

Carbon Taxes or Cap-and-Trade Systems?

From the perspective of economics theory, cap-and-trade regimes give policymakers confidence regarding the amount of emissions reduction by institutionalizing a cap for pollution. In contrast to carbon taxes, such systems seem to be politically both more saleable to public and more interesting to industries with lobbying power. Nonetheless, they make investment planning difficult for companies due to the unpredictability of the price of allowances, the volatility of permits price, and the widespread allocation of too many permits which prevents these systems from working appropriately.

Furthermore, in the implementation of tradable pollution permits, an enough-tightened cap that can help auctioning start (can keep permit prices high enough to signal polluters to react properly) is a daunting task; thereby not being easily achievable. This, in its turn, stops these systems from working as expected. In addition, cap-and-trade schemes are more complex to establish and more costly to administer than carbon taxes. Particularly, fraud risk and side information of powerful firms is problematic in cap-trade-systems.

While grandfathered cap-and-trade regimes are prone to suffer from the lobbying power of historical polluters, in auctioned systems both the starting allocation and re-allocation(s) of permits cause problems. Although in theory a cap can be defined in such systems reflecting the total amount of permitted pollution, determining the total number of permits (the total amount of pollutions) in practice is a daunting problem due to the difficulty of estimating critical natural capital.

Overall, it seems that carbon taxes are more transparent and easier to implement than cap-and-trade systems. Comparing the advantages and disadvantages of Pigouvian taxes and tradable pollution permits, the former approach (with a gradual increase in taxes) seems to be more applicable than the latter (even with a so-called tightened cap in order to phase out the right to pollute in a controlled way). Although the two market-based approaches to emissions reduction are roughly the same in theory, in practice carbon taxes are less problematic; in terms of both political longevity and environmental robustness. Overall, carbon taxes are more transparent, much easier to understand, and more effective than tradable pollution permits.

Cap-and-trade systems can be of “pure” or “hybrid” options. In the hybrid option of such systems there is a price ceiling and/or price floor. Like the case of carbon taxes, emissions price in the hybrid option of cap-and-trade schemes is exogenous. As Goulder and Schein (2013) emphasize, exogenous emissions pricing (whether through a Pigouvian tax or the hybrid option) has several attractions over pure cap and trade. As they clarify, “beyond helping prevent price volatility and reducing expected policy errors in the face of uncertainties, exogenous pricing helps avoid problematic interactions with other climate policies and helps avoid large wealth transfers to oil exporting countries.” Helping avoid an important form of carbon leakage can be added to this list.

Simultaneous Carbon Pricing Systems: Exploration and Advantages

According to the World Bank's (2018) report, to date 51 carbon pricing initiatives worldwide have been implemented or are scheduled for implementation; this consists of 25 emissions trading systems (ETSs), mostly located in subnational jurisdictions, and 26 carbon taxes primarily implemented on a national level. The report also categorizes the countries (e.g., Sweden, UK, Poland, France, and Portugal) in which ETSs and carbon levies have both been implemented or scheduled for implementation. Canadian provinces of British Columbia and Alberta are also included in this category. Return to figure 6 of this paper to find out more. Indeed, the simultaneous implementation of carbon taxes and cap-and-trade systems is possible.

Initially separate cap-and-trade schemes can be linked, like previously distinct carbon tax systems that can be harmonized; in that, their rates can be set equal (Goulder and Schein, 2013; Aldy, 2017).

> "Linkage and harmonization can yield cost savings. Linking separate emissions pricing programs yields greater abatement effort in the region with the initially lower emissions price and less abatement effort in the region with the initially higher emissions price, thus spurring equal abatement at overall lower costs. Linking once-separate cap-and-trade programs allows for further (cross-jurisdictional) reallocations of abatement effort and thereby yields further cost reductions beyond those generated by separate programs."

Arriving at a uniform international carbon tax, nonetheless, might raise some practical difficulties; as explained by Goulder and Schein (2013), it demands knowledge of the incidence of a wide range of existing energy taxes.

Other Climate Change Mitigation Policies Alongside Carbon Pricing

Economists have long endorsed carbon taxes and cap-and-trade systems, as the most acceptable carbon pricing tools to combat global warming to date (Aldy, 2017). Indeed, curbing CO2 emissions from fossil fuels is our main task facing global warming. Nonetheless, as a prominent figure in the field (Stern, 2015) emphasizes, carbon pricing should be complemented by other well-designed policies. Otherwise, the Paris target of “well below 2°C”, at the pace and on the scale required without unacceptable costs and distributional impacts, may not be achievable.

Such complementary policies to carbon pricing might include “the introduction of performance standards; new rules for city design, land and forest management, and investments in infrastructure; the development of new methods and technologies; and the use of financial instruments that foster private sector participation and reduce the risk-weighted capital costs of low-carbon technologies and projects” (Fay et al., 2015; and the World Bank’s Report of the High-Level Commission on Carbon Prices, 2017). These policies would work together with carbon prices and generally decrease the carbon price required to bring about the necessary emission reductions.

Regarding the implementation of other climate change mitigation policies alongside carbon pricing, it is important to highlight the potential advantage of carbon taxes over cap-and-trade systems. As explained by Goulder and Schein:

> "In the presence of a cap-and-trade program, introducing an additional GHG-reducing policy such as a performance standard might yield no further reductions in overall emissions. The reason is that overall emissions are determined by the overall cap or number of allowances in circulation. To the extent that the additional policy yields reductions in emissions by some facilities, the demand for emissions allowances falls. This causes the price of allowances to fall until all the allowances in circulation are again demanded. Overall emissions do not change. In contrast, introducing an additional GHG-reducing policy in the presence of a carbon tax can lead to a reduction in overall emissions. In this case the price of emissions – tax – does not change when the supplementary policy causes a reduction in emissions. For this reason the reduction caused by the supplemental policy does not lead to "emissions leakage," that is, an offsetting increase in emissions elsewhere. Overall emissions fall. (Goulder and Schein, 2013; p. 19)

See Fischer and Preonas (2010) as well as Shobe and Burtraw (2012) to find out more details about the advantages of carbon taxes over tradable pollution permits concerning the implementation of other climate change mitigation policies alongside carbon pricing.

Conclusion and Policy Advice

As summarized by the IPCC's definitive reports, the scientific community has reached a consensus that climate change is real, is caused by human emissions of greenhouse gases, and has dire consequences. Particularly Canada with the longest coastline in the world, high altitude regions, and significant Arctic territory, has already been hugely impacted by global warming.

Also, the international community has agreed so far that responding to climate change is not within the capacity of just one country or a group of nations. There has been a growing consensus of opinion, as well, on the application of carbon taxes and cap-and-trade systems to help save the environment, as the foundation of humans' prosperity. The idea is using tools of economics alongside power of capitalism to shape the behavior of polluters (individuals and firms) so that individual optimizations lead to outcomes that are good for the group as a whole. In this context, obviously the objective is conserving our critical natural capital, or simply saving the planet Earth for its inhabitants and next generations. And this goal can be achievable by gradually making carbon emissions more stringent or phasing out the right to pollute in a controlled way (Goulder and Schein, 2013; Aldy, 2017).

Since 1990s, each of the two market mechanisms of carbon pricing has been implemented in different countries and jurisdictions. The unsuccessful implementation of ETS in Europe to date versus the successful application of carbon taxes in Sweden brings to the forefront the conjecture of the superiority of carbon taxes to cap-and-trade systems. This conjecture is strengthened in the Canadian context by comparing Ontario's defunct cap-and-trade regime with the successful experience of imposing carbon levies to upstream businesses - oil refineries and power plants as clarified by (Murray and Rivers, 2015) - in the province of British Columbia. One of the findings of this major research paper is supporting carbon levies as the superior approach of carbon pricing. For a number of reasons, discussed in the body of the paper, Pigouvian taxes work better than tradable pollution permits.

Canada seems to be on the right track, therefore, by imposing levies on carbon emissions. By winning federal elections, it is expected that the Liberal government will continue pursuing the Greenhouse Gas Pollution Pricing Act (GGPPA), enacted by Prime Minister Justin Trudeau in April 2019. Although the provinces led by Conservative governments (Manitoba, Saskatchewan, Ontario and New Brunswick) have refused federal Liberal demands to enact their own carbon levies, Ottawa has already imposed its tax in those provinces, started April 1 at $20 per tonne and will rise to $50 per tonne by 2022. Following the loss of the Premier of Ontario in its case against the Act enacted by Prime Minister Trudeau before the Court of Appeal in June, it is foreseeable that the Supreme Court of Canada (SCC) would also reject the appeal of Ontario's Premier to the decision already made by the provincial Court of Appeal; confirming that the GGPPA is constitutional, and that it is especially with Parliament's jurisdiction to legislate in relation to matters of "national concern" under the section 91 of the Constitution Act, 1867; Peace, Order, and Good Government (POGG). This is expected, as well, to happen regarding the appeals of other conservative Premiers; like the Saskatchewan government has already appealed its unsuccessful challenge to the GGPPA and is expecting it to be heard in December.

A national carbon tax can and should be the centerpiece of Canada climate strategy. Indeed, the successful experience of British Columbia in levying pollution taxes can be a role model for other provinces too. Nonetheless, there might be valid concerns about the impact of such national policy on the international competitiveness of Canadian firms. Also, the argument that each province must decide on its own approach to carbon pricing should not be totally refuted. Therefore, it is fair to say: carbon pricing using the template of British Columbia works best in Canada, at least for start; a hybrid cap-and-trade system, or simultaneous implementation of carbon taxes and tradable pollution permits might be considered as well in some jurisdictions later. The crucial task, as Ostrom (2012) emphasizes in "The Future of the Commons", is building trust and creating a diverse environment favorable to discovering better solutions.

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Appendix A: Climate Change Timeline

Climate change is an old idea although it has only become a matter of global discussion in the last few decades. According to Heal (2017), it was first pointed out in the works of Joseph Fourier, a French mathematician who was in his early twenties in 1789 when French Revolution began. Based on his calculations, Fourier expected the earth to be considerably colder than it actually was, given its mass and distance from the sun. He suggested that the atmosphere acts as an insulator that keeps the planet warm – the first clear statement of the atmospheric greenhouse effect which, as Heal highlights, today is central to our understanding of the human effects on the climate. Swedish chemist Svante Arrhenius (1859-1927) was another nineteenth century scientist who contributed (in more details) to the understanding of human effects on the climate. He noted in 1896, Heal indicates, that carbon dioxide acts as an insulator, and its concentration increase in the atmosphere leads to warming.

Club of Rome's provocative "Limits to Growth"

The findings of Arrhenius and the enhanced greenhouse effect, Common and Stagl (2005) claim, did not attract much attention as a subject of scientific enquiry until 1960s. In was in 1972 that a controversial book titled "Limits to Growth" was published by the Club of Rome. It predicted dire consequences of unrelenting economic growth and faced Northern countries' criticisms for not including technological solutions. At the same time, Southern countries were incensed because it advocated the abandonment of economic development. The first World Climate Conference was held in Geneva in 1979 by WMO, the World Meteorological Organization. The conference, which focused on global warming and how it could affect human activity, issued a statement that called upon world governments to foresee and to prevent potential man-made changes in climate that might be averse to humanity's welfare. Several conferences and workshops took place during the 1980s. Particularly, it was in 1985 that a meeting in Austria of the World Meteorological Society, UNEP and the International Council of Scientific Unions reported on the buildup of carbon dioxide and other "greenhouse gases" in the atmosphere. They predicted global warming. (International Institute for Sustainable Development [IISD], 2012)

The birth of IPCC

In 1987, one of the most important and influential reports of the last part of the twentieth century was published by the World Commission on Environment and Development (WCED). That report which is titled "Our Common Future" (also known as Brundtland Report) weaved together social, economic, cultural and environmental issues and global solutions. It was, in fact, this report that popularized the term "Sustainable Development" (ibid). One year later, in 1988, the WMO and UNEP created the Intergovernmental Panel on Climate Change (IPCC), whose initial task was to prepare a comprehensive review and assessment with respect to the state of knowledge of the science of climate change; social and economic impact of climate change, possible response strategies (Henderson et al., 2017). To date, the IPCC has produced five sets of comprehensive reports; the last of which, known as AR5, includes three Working

Group (WG) reports and a Synthesis Report (IPCC, 2014). The first WG is titled "The Physical Science Basis"; the second, "Impacts, Adaptation, and Vulnerability"; and the third, "Mitigation of Climate Change". The IPCC is currently in its Sixth Assessment cycle. See IPCC (n.d.) for the 6th synthesis report (AR6).

United Nations Convention on Climate Change

The UN Conference on Environment and Development (UNCED), also called the Earth Summit, was held in Rio de Janeiro, Brazil, in 1992. Particularly, in that conference, two conventions were opened for signature (IISD, 2012): the Convention on Biological Diversity and the Framework Convention on Climate Change (UNFCCC). The objective of the UNFCCC is to stabilize greenhouse gas concentrations and enable sustainable economic development (United Nations Information Portal on Multilateral Environmental Agreements [InforMEA], n.d.). It is guided by principles that reflect the recognition of global environmental responsibility. Parties of the Convention, as highlighted by InforMEA, are committed to establish national inventories of emission and sinks, formulate and implement policies to adapt to climate change, sustainably manage ecosystems and integrate the considerations in social, economic and environmental policies. In meeting these commitments, Parties can take account of their different starting points and are required to submit periodic reports to monitor progress. The Conference of the Parties (COP) is the supreme decision-making body of the Convention that regularly reviews the adequacy of the commitments (ibid). The COP meets every year unless the Parties decide otherwise. There are Subsidiary

Bodies to support the COP; including, but not limited to, the Subsidiary Body for Implementation (SBI). Decisions made by the COP are reviewed and analyzed by the SBI. In case of a disagreement between Parties concerning the interpretation or application of the Convention, they are to seek a settlement of the dispute through negotiation.

The Kyoto Protocol

The first COP meeting (COP-1) was held in Germany in March 1995 and provided a strong political mandate (the Berlin Mandate) which led to the adoption of the text of the Kyoto Protocol to the UNFCCC at the COP-3 in Japan in December 1997 (IISD, 2012). This international treaty (the Kyoto Protocol) is intended to commit the state parties to reduce GHG emissions. The Kyoto Protocol, which is based on the principle of common but differentiated responsibilities, entered into force in early 2005 (InforMEA, n.d.). Differentiated responsibilities is the recognition of the fact that individual countries have different capabilities in combating climate change, owing to economic development (ibid); therefore, the obligation to reduce current emissions must be put on developed countries as they are historically responsible for the current levels of greenhouse gases in the atmosphere.

The Stern Review

On October 2006, Nicholas Stern presented a 700-page report on the Economics of Climate Change to the government of the United Kingdom (IISD, 2012). This report which is known as the Stern Review made the convincing economic case that the costs of inaction on climate change would be up to 20 times greater than measures required to address the issue at the time being. Public attention to climate change increased in 2007 when former U.S. Vice President Al Gore’s documentary, An Inconvenient Truth, was released and won an Academy Award. Simultaneously the IPCC’s alarming forecasts about the planet’s health made headlines. IPCC, as an independent scientific body and Al Gore won the Nobel Peace Prize together in that year (ibid). Also, it was in 2007 that an international treaty (Montreal Protocol) was signed to protect the ozone layer by phasing out the production of numerous substances responsible for ozone depletion.

The Paris Agreement

The Kyoto Protocol's first commitment period started in 2008 and ended in 2012. In the 18th COP in Qatar, states agreed upon the 2012 Doha Amendment to the Kyoto Protocol which establishes a second commitment period from 2013 to 2020. Later, negotiations were held in the framework of the yearly UNFCCC Climate Change Conferences on measures to be taken after the second commitment period ends in 2020. This resulted in the 2015 (COP21) adoption of the Paris Agreement (IISD, 2012), which is a separate instrument under the UNFCCC rather than an amendment of the Kyoto Protocol. The purpose of the Paris Accord is to prevent dangerous anthropogenic interference with the climate system (InforMEA, n.d.). It aims to do so by strengthening the global response to climate change in general, including by: committing to a long-term temperature goal; enhancing adaptive capacity and climate resilience; and making finance flows consistent with low-emission development pathways. The goals of the Agreement are to keep rising the global temperature well below 2°C above pre-industrial temperatures while pursuing efforts to limit the rise to 1.5°C; increase the ability to adapt; and make finance flows consistent with a pathway towards low emissions and climate-resilient development (ibid). These goals, consistent with the Kyoto Protocol, are to be achieved in a manner that reflects equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

The 48th session of the Intergovernmental Panel on Climate Change (IPCC, 2018) was convened from 1-6 October 2018 in Incheon, Republic of Korea, and announced on its Special Report on Global Warming of 1.5°C (SR15), as the target for 2030 to prevent climate catastrophe. The message of this new target is clear. Previous efforts (including the Paris Accord which targeted 2°C) have not been enough. In other words, countries should cooperate in action to meet the target.

To emphasize the need for international cooperation, said the 2018 committee for the Nobel Prize in Economics, the prize was given to William D. Nordhaus (for his contribution in and persuading governments to address climate change, preferably by levying a tax on carbon emissions) and Paul M. Romer for his critical role in fostering technological innovation. The award was announced just hours after the UN panel's emphasis on the urgency of large changes in public to limit the catastrophic consequences of rising temperatures. (Appelbaum, 2018)

The most recent Conference of the Parties (COP24) was held on December 2018, in Poland. In this Conference, the UN Secretary-General warned the negotiators on that the climate change is running faster than we are. He concluded his speech with this statement: Failing to agree climate action would “not only be immoral”, but “suicidal” (United Nations, 2018a). The conference had two goals (United Nations, 2018b): goal setting for the decreasing in the amount of GHGs, and helping the most vulnerable countries already being most impacted by climate change. At best, it can be said that countries in COP24 revived Paris Agreement despite the objections of USA and other climate deniers. They agreed on how to calculate GHGs, but not to decrease it. Also, they agreed on 100 billion dollars of help to vulnerable countries which was much less that expectations. While climate activists believed that the outcome of COP24 was not enough to meet the targets and save the world, the UN Secretary-General emphasized on the importance of dialogue.